A GEOGRAPHIC INFORMATION SYSTEM (GIS) BASED DETERMINATION OF ESTUARINE AND MARINE WETLAND AND SHORELINE CHANGES IN THE GALVESTON BAY ESTUARY FROM 1995 TO 2002

A Thesis

by

CHRISTINA CLAUDETTE TAYLOR

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

May 2008

Major Subject: Rangeland Ecology and Management

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Approved by:

Chair of Committee,	James Webb
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	Jay Rooker
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ABSTRACT

A Geographic Information System (GIS) Based Determination of Estuarine and Marine Wetland and Shoreline Changes in the Galveston Bay Estuary from 1995-2002. (May 2008)

Christina Claudette Taylor, B.S., Texas A&M University

Chair of Advisory Committee: Dr. James Webb

The purpose of this study was to identify and quantify estuarine and marine wetland and shore changes circa Galveston Bay Estuary (GBE) from 1995 to 2002 by using aerial photography and GIS mapping techniques. Aerial photographs in digital format were acquired from Texas Natural Resource Information System (TNRIS) and the Houston Galveston Area Council (HGAC); these photographs were selected because the images were taken at the time period desired, existed in digital formats at resolutions of 1 m or greater, and were in coordinate systems that were already in or could be properly aligned and georeferenced.

Maps for each of thirty quadrangles that include estuarine and/or marine habitats around the GBE were created, depicting wetlands and shorelines for the years 1995 and 2002 as well as changes between the two time periods. Polygons representing different habitats in 1995 were drawn while working at a scale of 1:4,000 or greater. Maps of habitats in 2002 and maps showing changes from 1995 to 2002 were produced by modifying individual 1995 polygons to document boundary shifts or habitat changes

from 1995 to 2002. All resulting maps were constructed at 1:24,000 scale in UTM NAD 83 coordinate system to match USGS quad maps. Areas of each habitat in 1995 and 2002 and changes between the two years were calculated in acres and comparisons were made.

There were four objectives developed to be examined by the creation of the new set of maps for GBE. They were to determine habitat changes during the time period in question, effectiveness of mapping technique, where differences in change occurred, and what type (i.e. erosion, development, accretion, etc.) of change occurred.

My analyses of these maps indicated that there were 117,670 acres of estuarine wetlands and 21,983 acres of unconsolidated estuarine and marine shores present in 1995. In 2002, these values changed to 116,534 acres of estuarine wetlands and 21,630 acres of estuarine and marine shores. The rate of wetland loss was estimated as 162 acres per year or 0.1% of all wetlands annually from 1995 to 2002. This rate has slowed from the previous rate of 405 acres per year or 0.4% in 1979 and remained the same as the 161 acres per year or 0.1% reported in 1993 for the GBE. Further, the results of my analyses indicated that losses from direct human influences (e.g. development, dredging, and filling) were less than losses associated with natural processes like erosion and subsidence.

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I would like to acknowledge the Galveston Bay Estuary Program (GBEP) for their support of this research. GBEP provided maps and aerial photography data in digital format. They also provided previous reports and information as well as financial support for this research. I would also like to thank the Houston Galveston Area Council for the use of their aerial photography.

A special thank you goes to my committee and chairman, Jim Webb, for their input and guidance through this research. The technical advice and research support of Dr. John Jacobs and members of his research staff was greatly appreciated. Finally, thank you to all the undergraduate research assistants, who provided mapping support.

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INTRODUCTION

Background

Determination of the area of wetland change and the reasons for this change in the Galveston Bay Estuary, Texas are important for several reasons. Wetlands are important in fisheries productivity as well as for wildlife habitat, improving and maintaining water quality, erosion prevention, and flood control (Moulton and Jacob 2000). Galveston Bay Estuary (GBE) is the seventh largest estuarine system in the U.S. and it accounts for 28% of Texas commercial fisheries and 30% of the blue crab harvest (Pulich and White 1990). At the same time, the GBE has a high degree of industrial and residential development and has one of the largest shipping ports in the world.

Historically, there have been a number of natural and anthropogenic reasons reported for habitat changes observed around the GBE. The natural causes for wetland change include accretion, burial by deposition and washover events, and successional growth of wetland plant communities. Anthropogenic effects on wetland change include excavation or dredging of channels, urban or residential development, depositing of fill material, and creation of new marshes. The changes caused by erosion and subsidence are a combination of natural and human induced factors affecting change on the habitat. These problems have been occurring in the GBE since the 1950's (Johnston and Ader 1983, Dahl 1990). These factors are further evidenced by an increase in recreational marinas and boating. The effects of development on wetland loss are apparent as areas

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This thesis is in the style of *Estuaries and Coast*.

of level fill material or buildings. A significant anthropogenic impact on the GBE's habitats is dredging to keep open the economically important shipping channels. The periodic placement of dredged material in disposal sites continually causes changes in hundreds of acres of wetlands existing in the diked containment sites. These anthropogenic disturbances are usually clustered in densely populated areas.

Another cause of wetland loss is relative subsidence or areas where the land elevation has appeared to drop in relation to sea level as evidenced by a change in vegetation and hydrology patterns of the area. Subsidence is sinking land, but it is exacerbated by rising sea level. The two together are referred to as relative sea level rise. The U.S. reported 26,000 km^2 of land subsidence nationwide from water removal. Subsidence is most often reported in coastal and riverine areas where flooding potential increases or areas become permanently inundated (Panel on Land Subsidence 1991). Land also subsides when natural gas and subsurface fluids are removed causing settling of the soil above. In the Chocolate Bayou area on the southwest side of the GBE there was a 0.55-m drop in elevation since 1943 due to oil, gas, and water removal combined (Narasimhan and Goyal 1984). Water removal in the Houston-Galveston Subsidence District resulted in a 2.13-m drop in elevation between the years of 1943-1974. The San Jacinto and Goose Creek Field areas, in the northern portion of GBE, have had a 2.70 m drop since 1943 (Holzer 1984). Subsidence has been a problem in this area for a hundred years, but has just recently been studied (Holzer 1989). There is also some subsidence due to fault lines (either natural or caused by subsurface fluid removal) shifting and this factor was responsible for the loss of wetlands along the bayside of the Bolivar Peninsula (White et al. 2004).

Creation, as used in this paper, is the term that refers to the “positive” anthropogenic effects of creation, restoration, or mitigation of new wetlands. Wetlands created with dredge material have been widely used and studied as a way to restore lost wetlands (Minello 2000; Streever 2000). Terracing is used to describe the other widely used technique in the northern Gulf of Mexico, especially along the Louisiana and northeastern Texas coast (Good, 1993; Rozas and Minello 2001). The benefits of these wetlands are still being studied (Delaney et al. 2000 and Shafer and Streever 2000) and it is believed that they do not provide equivalent functions to that of natural marshes. Minello (2000) showed that there was no difference in diversity of species in newly created marshes; however, densities of commercially important species were lower and were smaller in size. While creation of new marshes is common in the GBE, the amount of creation is not known or if these created marshes offset any of the wetland losses in GBE.

The GBE is divided into three primary habitat classifications (open water, wetlands, and unvegetated shores and flats) for calculations made in this paper. Open water referred to bodies of water deeper than 2 m that comprise the GBE and the Gulf of Mexico. This habitat is not being discussed in too much detail; this research is focusing on wetland and shore habitats. Wetlands are transitional areas between open water and higher elevation inland areas that support hydrophytic vegetation. This paper is only covering tidally influenced estuarine wetlands. This group will be subdivided into regularly flooded (low) marsh (E2EM1N), irregularly flooded (high) marsh (E2EM1P), shrub (E2SS) and tree (E2FO) habitats. According to species list compiled by White and Paine (1992), E2EM1N habitats are dominated by *Spartina alterniflora* (smooth cordgrass), *Juncus roemerianus* (needlegrass rush), and *Scirpus* sp. (bulrushes) and E2EM1P habitats are dominated by *Spartina patens* (marshhay cordgrass), *Distichlis spicata* (seashore saltgrass), and *Borrichia frutescens* (sea oxeye). The last category, unvegetated (or unconsolidated) shores (E2US or M2US) and flats (E2UB), can be subdivided into three categories. Shores are unvegetated areas adjacent to bodies of open water and can be marine (Gulf of Mexico) or estuarine (bay side) shores. Flats are areas of sand that are not adjacent to the water, and are usually separated from open water by marsh. Flats can be bare ground or sparsely (<20% cover) vegetated.

Calculations of the amount of estuarine wetlands in the GBE have been made from aerial photos at four different time periods, mid-1950's, 1979, 1989, and 1993. White et al (1993) compared three time periods and reported 117,640 acres in the 1950's, 105,880 acres in 1979, and 108,160 acres of estuarine wetlands in 1989. The National Wetlands Inventory (NWI) Group of the U.S. Fish and Wildlife Service (USFWS) released another set of NWI inventory quadrangle maps from 1993 for the Texas coast. The 1993 quadrangle maps for the GBE represent a more recent inventory, but wetland totals did not change between 1989 and 1993. In 2002, White et al. (2004) and others did a partial change analysis of a study area including GBE's Bolivar Peninsula, Galveston Island, and Follets Island. They reported 19,048 acres of wetlands present in 2002. However, complete bay system comparisons of wetland change have not been made since 1989 (White and Lawrence 1993).

Calculations of the amount of unvegetated shorelines have been made for estuarine (bay) and marine (gulf) shores in the GBE from aerial photography for the four different time periods mentioned. The amounts of shorelines and flats were 18,182 acres, 26,258 acres, and 21,352 acres in 1950's, 1979, and 1989 respectively (White et al., 1993). Other shoreline areas were mapped from photography in 1930, 1956, 1982, and 1995 (Gibeaut et al. 2003). Gibeaut et al. (2003) measured the rate of shoreline change in the West Bay of the GBE and its associated smaller bays and found that 48% of the shoreline was retreating, 46% was stable, and 6% was advancing seaward. In 2002, a partial study of the Bolivar Peninsula, Galveston Island, and Follets Island of GBE was completed by White et al. (2004) and others mapping changes in shoreline. They reported 1,904 acres of tidal flats and 1,373 acres of Gulf shoreline for this region.

The Galveston Bay Estuary Program, which is a part of the Texas General Land Office, is charged with management of Galveston Bay resources. This group, along with other state and federal agencies, non-profit resource protection agencies, and individuals are interested in whether the trend in wetland losses has stopped or been reversed. Data on change are needed to determine if actions taken to stop subsidence, restore habitats, educate the public on wetland values, etc. have stopped or reduced wetland loss.

Objectives

Aerial photography and GIS were used to map and analyze changes in the GBE. It also considered shoreline changes and movements along the coast near the mouth of the bay system. This research relied on previous studies from the area for much of the habitat verification. This should also allow for comparison between past and future studies of wetlands loss for the GBE.

GIS utilizing aerial photography is an effective platform for displaying and quantifying the changes in coastal wetlands. Current maps of the wetlands of the U.S. are available in GIS format on the U.S. Fish and Wildlife Service's (USFWS) National Wetland Inventory (NWI) website. Existing wetland inventories for the GBE stem from the NWI and have relied primarily on aerial photo interpretation and GIS software for map-making and aerial calculations (Johnston and Ader 1983; White et al. 1993).

The objectives of this study were to 1) determine whether change to estuarine wetland area has occurred since the last inventory and comparison done in 1989; 2) estimate the amount of wetlands that currently exist in the GBE and what portion of existing wetlands are from creation across the years in question; 3) identify the reasons for change; and 4) determine which areas of the GBE (quadrangles) have experienced the most wetlands change.

To document the current area of wetlands and to calculate changes from a previous time period, it was necessary to compare recent maps to previous maps. As a result analyses were performed to determine whether existing maps were accurate and whether the existing maps were modified to properly calculate changes.

Hypotheses

To accomplish the above objectives, hypotheses and testing procedures were developed to determine whether the boundaries and areas of wetlands (polygons in GIS) were accurately drawn in each time period and whether changes could be properly measured. I hypothesized 1) that there was no change in GBE estuarine wetland area and shores and marine shores between the years 1995 and 2002; 2) that there was no spatial pattern to GBE wetland and shoreline change—as indicated by comparing change between USGS quadrangles, and 3) that there was no difference between natural and human-related causes of change in GBE wetland and shores. In order to have access to more recent maps, I assumed that there was no significant difference between the 1993 NWI maps and the maps created by aligning with the 1995 aerial photography.

MATERIALS AND METHODS

Methodology Background

With the increased reliability and accessibility to GIS and remote sensing, the availability of spatially-explicit natural resources data is increasing. So it is important to ensure that the data available are accurate and updated regularly. With software and technique improvements, as well as training and practice in recognizing vegetation patterns and habitat shifts in aerial photography, it is becoming easier to track changes in both the location and area of specific natural resources such as wetlands.

Aerial photography is a widely used tool for analyzing and tracking changes in natural resources and has been used in numerous studies to identify vegetation changes, percent cover, and habitat area shifts. Coastal estuarine and marine habitats need higher resolution photography than what is commonly used in other inland areas in order to be useful in mapping change. In many cases, other knowledge and field information is needed for accurate mapping (Higinbotham et al. 2004). Loss or accumulation of estuarine wetlands is based primarily on tonal patterns of the imagery. Changes in tonal pattern (color, shading, texture, and shape) help to identify habitat change between open water, bare ground, vegetation types, hydrology regimes, roads and buildings in urban areas. Identification of wetland boundaries on aerial photographs will vary according to scale of the photograph, time of year the photograph was taken, quality of the photograph, and most importantly, the soil moisture at the time of the photograph (Watson 1997). It is not possible to hold all variables constant across intervals of time and interest.

Documentation of the present status of wetlands requires recent photography. Nearly complete aerial coverage of the Galveston Bay area is available for 2002. To make change calculations, one requires a set of base maps or images to compare to the recent photography. For this research, I decided to modify existing 1993 maps, however, differences between 1993 maps and the subsequently created maps can be present due to classification and drawing differences between the three sets of maps that could affect determinations of area.

Properly georeferenced imagery is an important development in accurately making wetland maps, overlaying them on quad maps, and determining acreage of wetlands. Complete aerial coverage in 1995 at 1 m resolution in color infrared that matches the alignment of the 2002 photography is available at no cost. However, wetland boundaries from the 1993 maps do not match the 1995 photography, known as digital ortho quarter quads (DOQQs). Without the imagery used in the original mapping of the 1993-wetland maps, it was not possible to identify true habitat changes or alignment problems between the layers. Realigning the 1993 maps to the 1995 photography appeared to be an excellent alternative to the development of more recent maps. There also were questions about how some polygons were classified. A fundamental question in the time comparisons was whether the different acreages calculated at each time period were actual changes or whether the differences were due to differences in accuracy of drawings or classification.

Software, Maps and Digital Data

Materials used in the research included ESRI ARCGIS 8.3 and 9.0 software, maps and acreage calculations from previous studies, subsidence data, and digital data available for the GBE. Maps included in this project cover all habitats classified at the system level as estuarine and marine adjacent to the GBE. There are approximately thirty quadrangles around the GBE that include estuarine and coastal marine habitats as reported by White et al. (1993). The quads with estuarine habitats connected to the Galveston Bay System are listed in Table 1 and depicted in the study area map in Figure 1.

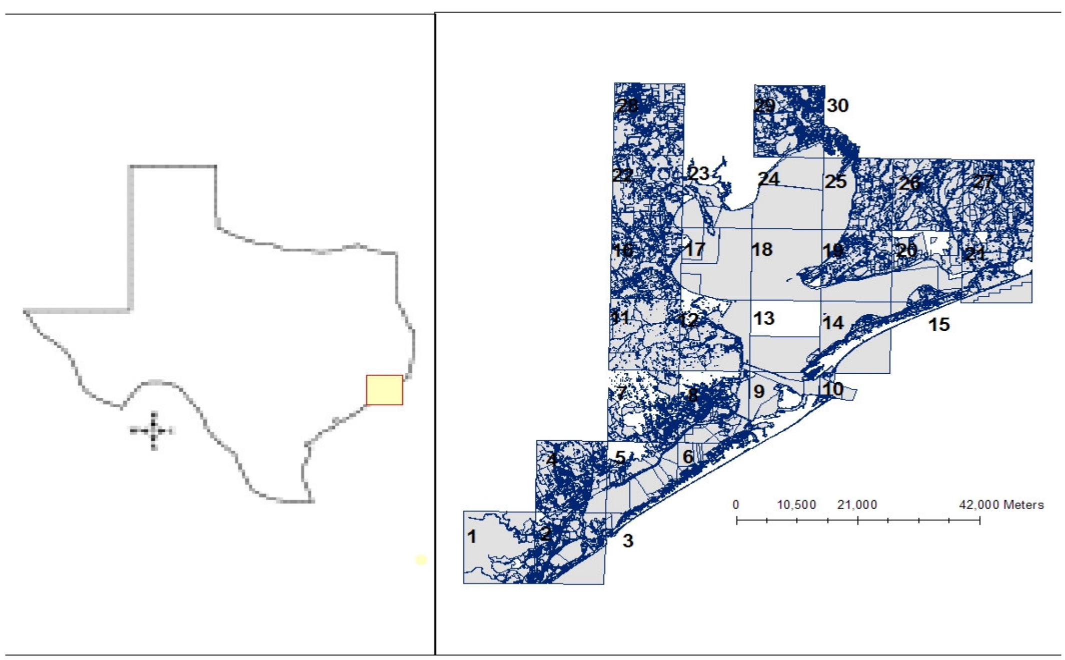

Figure 1: Map of the study area for the Galveston Bay Estuary (GBE) estuarine and marine habitat change analysis. Thirty quads circa GBE as identified in Table 1.

Table 1: Quadrangles that contain estuarine and marine habitats as classified by White et al. 1993 and depicted in Figure 1.

1.Oyster Creek	12.Texas City	23.Morgans Point
2.Christmas Point	13.Port Bolivar	24.Umbrella Point
3.San Luis Pass	14.Flake	25.Oak Island
4.Hoskins Mound	15.Caplen	26.Oyster Bayou
5.Sea Isle	16.League City	27.Stanislind Reservoir
6.Lake Como	17.Bacliff	28.Highlands
7.Hitchcock	18.Smith Point	29.Cove
8.Virginia Point	19.Lake Stephenson	30.Anahuac
9.Galveston	20.Frozen Point	
10.The Jetties	21.High Island	
11.Dickinson	22.La Porte	

Wetland maps for 1993 were available as vector data in the form of National Wetland Inventory (NWI) polygon features and were downloaded from the NWI website as Arc View shapefiles. These files were available for all the United States Geological Survey (USGS) quadrangles in Table 1 and were analyzed in the Universal Transverse Mercator (UTM) projection, North American Datum (NAD) 1983 for Zone 15. Aerial photography for this project came from a number of sources for the two years of interest. For the first set of images, 1995 Color Infrared (CIR) Digital Ortho Quarter Quad's (DOQQs) were downloaded from the Texas Natural Resources Texas Orthoimagery Program and VARGIS. They were in the UTM projection NAD 1983 Zone 15 at 1-meter resolution. These images cover all of the quads in Table 1. The second set of images was from H-GAC (Houston-Galveston Area Council) 2002 real color aerial photography. These images were projected in the state plane coordinate system for Texas South Central Zone (FIPS 4204) NAD 1983 at 1-foot resolution. The second set of images covered the quads around Trinity and Galveston Bay as well as quads along northern portions of East Bay. The third set of images was a 2002 composite CIR imagery of lower Galveston Bay in the format of an ecw file from the Texas General Land Office. These 2002 ECW composites are in the UTM projection, NAD 1983 Zone 15 at 1-meter resolution. These images covered most of the lower bay system including quads along eastern portions of Galveston Bay and most of West Bay, Bolivar Peninsula and Galveston Island.

All raster and vector datasets for this project were processed using ESRI ArcGIS 8.x or ArcGIS 9.0 software on Windows-based microcomputers. Images were brought into the project file and projected "on- the –fly" to State Plane Texas South Central Zone in order for the images to overlay properly. All map files created for this project were created in UTM projection NAD 1983 Zone 15 as feature classes in a geodatabase. Files were created and saved to a TAMUG GIS server for retrieval and analysis.

Method for Creating Maps

Wetland maps for each of the thirty USGS quadrangles in Table 1 were created for the years 1995, 2002, and a map of the changes in the estuarine system for the seven-year period from 1995- 2002 with labels explaining the presumed causes of change. Two primary methods for creating these maps were implemented to determine which method was most accurate and time efficient.

The NWI quad maps from 1993 and aerial photos for 1995 were imported into an ArcGIS Desktop project file. For the first method, a new shapefile was created and labeled for each of the quads (ex. Cove_95). The projection and coordinate system for a layer image were set during layer creation. A habitat field was added to the attribute table of each quad layer to allow classification by habitat based on the Cowardin classification system. Classifications and habitat descriptions are listed in table 2. Then, an edit session was conducted to create polygons either by tracing existing polygons from the 1993 NWI maps for features that have not changed or creating new or modified features where changes have occurred or boundaries appear to be inaccurate based on tonal patterns of the 1995 images. The second method for creating 1995 wetland maps was to edit the 1993 vector data to match the boundaries on the 1995 imagery. This was done by reshaping or cutting estuarine polygons that appeared to have different boundaries or changes from those labeled in 1993. Polygons that were not labeled in 1993 were added. When all the polygons for each particular quad were drawn and identified, shape files were converted to feature classes within a geodatabase in which perimeter length and area could be calculated for each polygon. After all of the 1995 feature classes had been created, a base map of estuarine wetland habitats for 1995 exists for future comparisons. In both methods, upland area and palustrine wetlands were not drawn or modified unless the boundary was shared with an estuarine wetland or open water habitat.

To classify habitat for 2002, all aerial photos for 2002 were added to the project. Then, 2002 wetland habitat maps were created. For method one, 1995 feature class layers were duplicated in Arc Catalog and relabeled Quad_ Chng02. Fields that are called from_95, new_02, reason, and habitat_2002 were added to each of the changes_02 feature class files. Then, these feature class files were added to the project layer and overlain on the 2002 images. The polygons were modified to indicate any habitat changes, either in classification, size, or shape based on tonal patterns, shade, or texture of the imagery. Modifications were made by reshaping and cutting polygons into different parts that either retained old labels or were given new labels for a new habitat. Habitats that were not on the 1995 imagery were added and labeled. Any habitat that did not have 2002 imagery available was cut at the edge of the image, but the new polygon created by the cuts retained the previous label in attribute table because a change cannot be identified. The 2002 changes map were then be overlaid on the 1995 feature class, and the two feature classes were combined to form a new feature class labeled Quad_9502. These unions created one file that contains the 1995 map, areas of change, and a complete 2002 map. For the second method, quads previously labeled Quad_9502, in the creation of the 1995 feature classes, had the following fields added to the attribute table from_95, new_02, reason, and Habitat_2002. Then the polygons were cut and the habitats of the new polygons labeled.

When both the maps of 1995 and 2002 wetlands were created, the attribute tables were edited to eliminate typing errors and any label inconsistencies. Errors from drawing such as slivers, duplicate polygons, and overlaps were corrected.

Table 2: List of Cowardin classifications and corresponding habitat descriptions as used in this research. Modified from Cowardin et al 1979.

CLASSIFICATION	DESCRIPTION
E1UBL	Estuarine subtidal unconsolidated bottom permanently flooded
E2EM1N	Estuarine intertidal emergent persistent vegetation regularly flooded
E2EM1P	Estuarine intertidal emergent persistent vegetation irregularly flooded
E2SSP	Estuarine intertidal scrub shrub irregularly flooded
E2UBM	Estuarine intertidal unconsolidated bottom irregularly exposed
E2UBN	Estuarine intertidal unconsolidated bottom regularly flooded
E2UBP	Estuarine intertidal unconsolidated bottom irregularly flooded
E2USN	Estuarine intertidal unconsolidated shore regularly flooded
E2USP	Estuarine intertidal unconsolidated shore irregularly flooded
M1UBL	Marine subtidal unconsolidated bottom permanently flooded
M2USN	Marine intertidal unconsolidated shore regularly flooded
M2USP	Marine intertidal unconsolidated shore irregularly flooded

Methods for Determining Cause of Change

Each polygon identified as having changed was given an explanation for that change in a separate field within the attribute table. The labels given and reasoning for these labels follow in Table 3. Since the category of erosion was large and occurred in nearly all of the quads this category was divided into four subgroups. The use of subgroups provides more detail on the actual cause of habitat change. Erosion/marsh depicted loss of both high and low wetland marsh habitats. Erosion/shore and Erosion/upland depicted change from shore to open water and change from upland to some other habitat, respectively. Erosion without a subgroup depicts changes in area or retreat of habitat boundaries without completely losing or changing the habitat. No photo was recorded for 43,480 acres; these areas were not available for a true change analysis because 2002 imagery was not available. Therefore in the attribute tables for each quad, the habitat label remains the same as what was recorded for 1995.

Table 3: Classification of the types of changes occurring in estuarine and marine system habitats of the Galveston Bay Estuary.

TYPE OF CHANGE	EVIDENCE USED TO IDENTIFY TYPE
Accretion	Increase or building out of unvegetated shores
Burial	Accretion of sediments covering an area of previously vegetated land
Creation	Created, mitigated, or restored wetlands (i.e. linear terrace shapes or small clustered spoil islands).
Development	Areas where buildings (residential, commercial or industrial) or roads replace wetland polygons
Erosion	Retreating of a shoreline or vegetation line.
Excavation	Areas dredged for channels, marinas or ponds.
Fill	Areas that appear buried by manmade soil deposits, usually near development sites
Growth	Increase in area of marsh vegetation
Manmade	Areas where changes are due to structures (geotubes, groins, breakwaters, etc.) being installed to control or limit erosion
No Photo	Photography not available for 2002 verification of changes.
Subsidence	Areas that have a change in elevation as evidenced by increased hydrology (i.e. flooding).

Method for Creating Tables and Determining Change

Acreage fields were added to each attribute table in ArcGIS using the conversion feature to convert the shape area from square meters to acres. Queries were performed to determine the amount in acres of each habitat identified per quad by selecting the fields HABITAT_1995 and ACRES and calculating the sum total of the habitats. All queries were performed using Microsoft Access database query wizards that would automatically update as errors were found and corrected and recorded each query that was completed so time was not wasted on duplicate queries. Once queries were complete for each of the thirty quads, results were copied to Excel and combined into a table identifying the amount of each habitat identified in the GBE and the total amount of estuarine and marine habitats in each quad. Then, additional queries were performed for each quad using the fields HABITAT_2002 and ACRES, and a separate table was created to show the total wetland and shore amounts for 2002. Comparison tests were run in Excel using the data from these two tables to determine if there was a significant amount of wetland and shore change in the GBE. A query to identify the change type was performed to identify which change types occurred in each quad and which change types were most common in the GBE.

Method for Comparing and Analyzing Data Sets

To test the accuracy of the methods described above and compare my data to the previous NWI data from the 1993 study by White (1993), seven quads were randomly selected to compare boundary lines and label changes from the 1993 data to the 1995 data. In each of these seven quads, there were a minimum of twenty-five and a maximum of fifty-nine polygons selected from the 1995 map of each quad. The 1995 imagery sets were used as the base for comparison because digital imagery was not available for the 1993 map. The randomly selected polygons were then overlaid on the 1993 polygons. Then, the object identification, habitat classification, area, and distance between the old and new boundary lines were recorded. A paired t- test with alpha of .05 was performed using Excel software to determine if there was a significant difference in the amount of estuarine or marine habitat area due to modification of the boundary lines. Polygons where areas were not recorded or available for both habitats were not included in the paired t-test. The average distances between old and new boundaries were measured for forty-six of the polygons from five different quads. These averages were compared to determine if there was significant boundary movement between 1993 and 1995. Further statistical analysis of the same polygons used above compared changes in wetlands due to classification changes between the 1993 map and the 1995 map.

SPSS was used to analyze changes between quads and change types described above in Table 3 by performing a MANOVA followed by a S-N-K mean separation test at an alpha level of 0.05.

RESULTS

The map created from the 1995 aerial imagery (Figure 2) shows that the highest amounts of estuarine wetland habitats for the GBE lay in the northeastern portion of East Bay and the southwestern portion of West Bay. The 1995 maps for each individual quad are provided in Appendix A. In 1995, there were totals of 117,670.3 acres of estuarine wetlands and 21,983.4 acres of estuarine and marine shoreline and salt flats (Table 4). There were 71,746 acres of high marsh (E2EM1P), 44,821 acres of low marsh (E2EM1N) and 1,102.6 acres are shrubs or trees (E2SS/E2FO). Unvegetated flats and shores account for 8,605 and 9,702 acres, respectively. Finally, marine beaches made up 2,177 acres of the total habitat. High Island, Christmas Point, Flake, Frozen Point, and Sea Isle quads contained the highest percentages of wetland and shore habitats. Christmas Point, Frozen Point, and Sea Isle were the quads containing the highest acreages of low marsh; while High Island, Lake Stephenson, and Frozen Point had the greatest amount in acres of high marsh. A further breakdown of all the Cowardin classifications for the estuarine and marine systems with the various classes and modifiers recorded for each quad is presented in Appendix D-1.

The map created from the 2002 imagery (Figure 3) shows that the areas of highest concentration of wetlands were in the same regions of the GBE; the extreme portions of East Bay and West Bay still have the most estuarine wetland habitats. The 2002 maps of individual quads are provided in Appendix B. There were a total of 116,534 acres of estuarine wetlands and 21,630.6 acres of estuarine and marine shoreline in the GBE recorded for 2002 (Table 5). There are 70,871, 44,568, and 1,094 acres of high marsh (E2EM1P), low marsh (E2EM1N), and shrub (E2SS) habitats respectively.

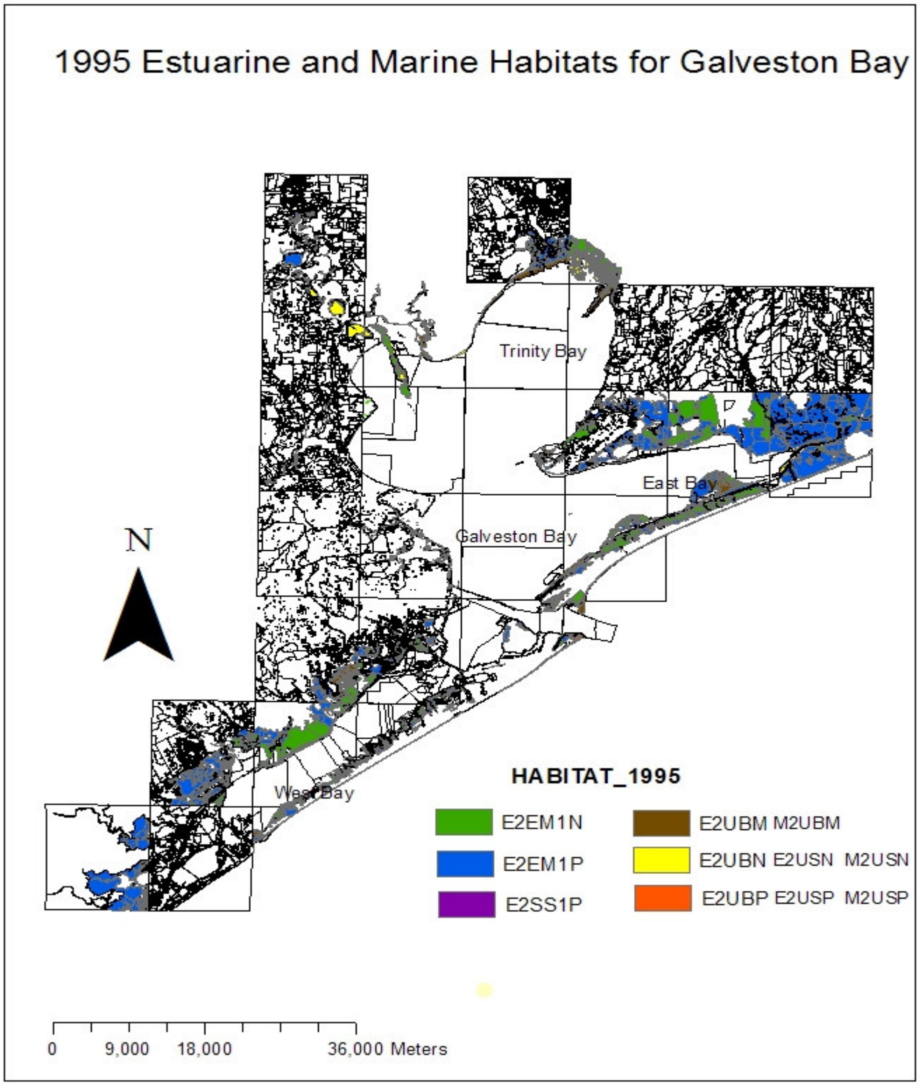

Figure 2: Map of estuarine and marine habitats located around the Galveston Bay Estuary, Texas as of 1995.

Table 4: Total acreage of wetland and unconsolidated habitat per quad based on data recorded from the 1995 map for Galveston Bay Estuary, Texas.

	LOW MARSH	HIGH MARSH	SHRUBS/TREES	SHORE/FLATS	TOTAL
ANAHUAC	2648.0	42.1	0.7	1332.1	4022.8
BACLIFF	256.6	20.0	3.3	122.3	402.2
CAPLEN	1417.1	824.2	0.0	417.0	2658.4
CHRISTMAS POINT	9146.4	3469.5	362.4	3087.9	16066.2
COVE	253.9	2956.4	14.4	1270.6	4495.4
DICKINSON	6.0	65.1	0.0	81.5	152.6
FLAKE	2665.5	1164.1	13.6	1087.5	4930.7
FROZEN POINT	8163.0	7720.6	49.9	1079.7	17013.2
GALVESTON	574.6	485.2	24.8	442.8	1527.5
HIGHLANDS	94.5	886.0	124.4	781.9	1886.8
HIGH ISLAND	880.2	20785.3	25.8	454.5	22145.9
HITCHCOCK	1471.6	1651.9	0.0	1148.7	4272.3
HOSKINS MOUND	2152.8	5432.3	68.6	612.3	8265.9
LAKE COMO	1223.8	695.8	50.2	336.3	2306.2
LAKE STEPHENSON	1703.8	8031.1	1.6	286.9	10023.5
LAPORTE	67.0	145.3	0.0	1761.2	1973.4
LEAGUE CITY	27.3	302.7	34.6	737.6	1102.2
MORGANS POINT	1048.8	199.8	114.0	1818.3	3180.9
OAK ISLAND	110.9	168.1	20.3	1339.3	1638.6
OYSTER BAYOU	0.0	651.9	0.0	11.4	663.3
OYSTER CREEK	745.3	7397.2	6.5	39.4	8188.4
PORT BOLIVAR	181.6	129.6	7.9	236.9	556.0
SAN LUIS	347.2	501.5	0.0	461.1	1309.8
SEA ISLE	5841.4	2575.3	73.8	784.0	9274.4
SMITH POINT	369.4	99.1	13.7	396.2	878.4
STANISLIND RESERVOIR	0.0	2198.3	0.0	6.5	2204.8
TEXAS CITY	478.9	530.9	15.3	465.3	1490.4
THE JETTIES	177.8	155.0	0.0	567.6	900.4
UMBRELLA POINT	1.8	2.1	0.0	385.2	389.1
VIRGINIA POINT	2766.2	2459.7	76.8	431.2	5734.0
TOTAL	44821.5	71746.2	1102.6	21983.4	139653.7

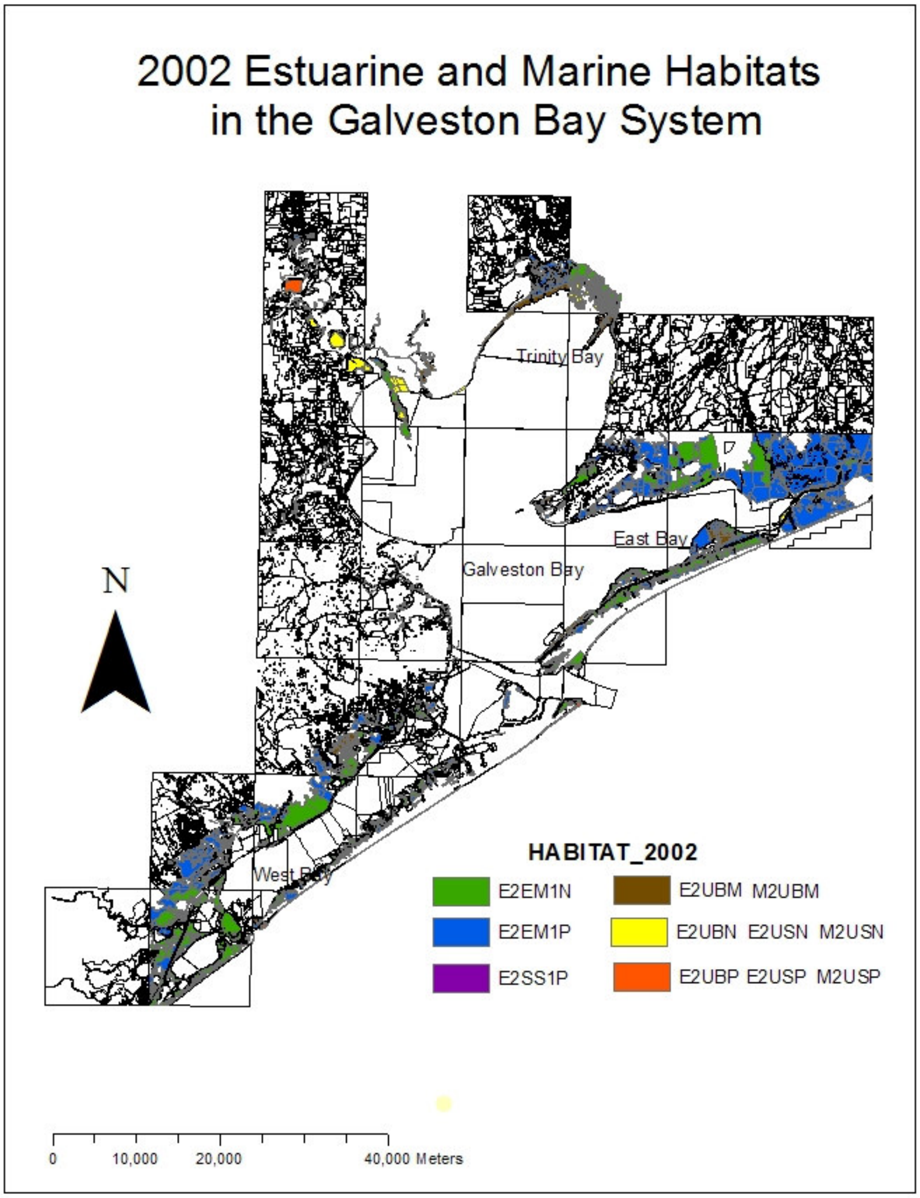

Figure 3: Map of estuarine and marine habitats located around the Galveston Bay Estuary, Texas as of 2002.

Table 5: Total wetland and unconsolidated habitat acreages per quad based on the data recorded from the 2002 map of Galveston Bay Estuary, Texas.

	LOW MARSH	HIGH MARSH	SHRUBS/TREES	SHORE/FLATS	TOTAL
ANAHUAC	2673.7	42.0	0.7	1364.8	4081.2
BACLIFF	257.8	20.4	2.9	125.1	406.2
CAPLEN	1421.4	814.4	0.0	452.2	2688.0
CHRISTMAS POINT	9120.2	3468.6	358.8	2523.6	15471.2
COVE	260.4	2926.8	14.9	1278.3	4480.4
DICKINSON	5.9	65.3	0.0	71.4	142.6
FLAKE	2594.5	1130.4	13.6	1004.8	4743.3
FROZEN POINT	8122.0	7687.2	54.8	1099.6	16963.6
GALVESTON	486.0	526.1	28.2	219.3	1259.6
HIGHLANDS	99.3	229.8	124.9	1414.4	1868.3
HIGH ISLAND	930.9	20773.4	25.9	508.5	22238.7
HITCHCOCK	1469.9	1635.2	0.0	1147.0	4252.1
HOSKINS MOUND	2143.5	5432.0	68.6	503.6	8147.7
LAKE COMO	1180.0	692.8	41.9	374.8	2289.6
LAKE STEPHENSON	1708.7	8047.1	2.1	265.2	10023.1
LAPORTE	108.1	145.3	0.2	1736.8	1990.4
LEAGUE CITY	50.8	294.4	33.0	711.4	1089.6
MORGANS POINT	1035.9	194.2	110.7	2403.7	3744.5
OAK ISLAND	107.1	189.4	20.3	1332.0	1648.9
OYSTER BAYOU	0.0	651.9	0.0	11.4	663.3
OYSTER CREEK	745.3	7397.2	6.5	39.4	8188.4
PORT BOLIVAR	213.0	130.5	7.9	183.9	535.3
SAN LUIS	311.6	535.3	0.0	456.5	1303.3
SEA ISLE	5583.2	2588.0	69.2	462.1	8702.5
SMITH POINT	363.1	97.1	9.6	366.0	835.8
STANISLIND RESERVOIR	0.0	2198.3	0.0	6.5	2204.8
TEXAS CITY	466.3	501.1	13.8	464.2	1445.4
THE JETTIES	316.2	98.0	1.3	266.1	681.6
UMBRELLA POINT	3.4	0.2	0.4	510.0	514.0
VIRGINIA POINT	2790.0	2359.5	83.8	327.9	5561.3
TOTAL	44568.4	70871.6	1094.0	21630.6	138164.6

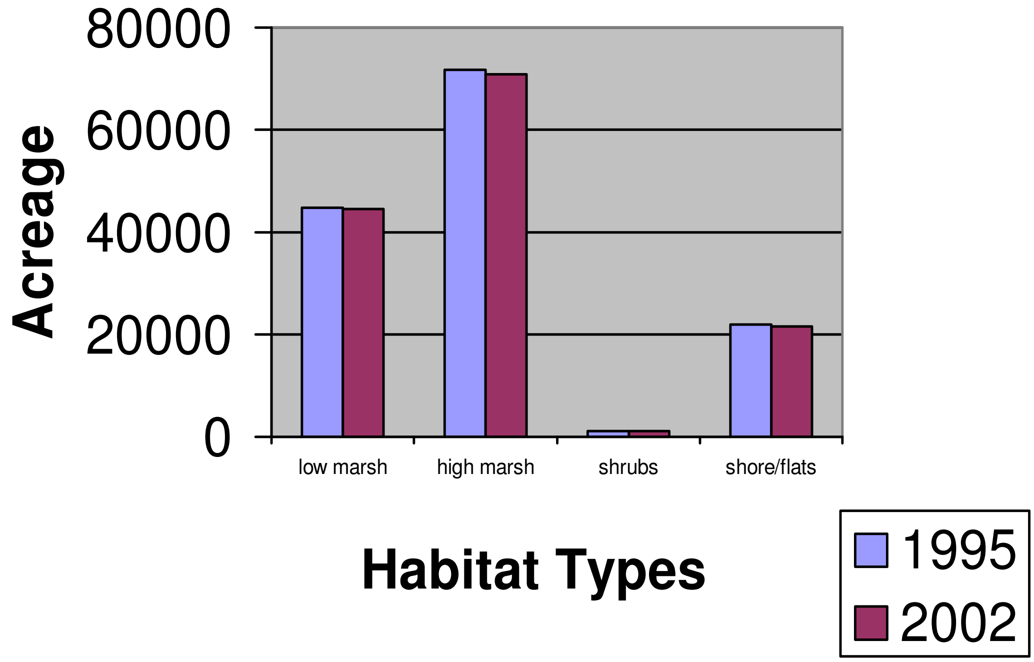

Figure 4: Total acres of estuarine wetland, estuarine shore and marine shore habitats mapped in 1995 versus the total acres of the same habitats mapped in 2002 for the Galveston Bay Estuary (GBE).

Unvegetated flats and shores account for 9,422 and 8,765 acres respectively. Finally, marine beaches made up 1,908 acres of the total habitat. Christmas Point, Frozen Point, and Sea Isles remain the top three low marsh acreage containing quads. High Island, Lake Stephenson, and Frozen Point remain the top three high marsh containing quads. A further breakdown of the Cowardin classification system habitats reported for each quad in 2002 is reported in Appendix D-2.

There were minimal habitat acreage differences in the two maps depicted by the bar graph in figure 4. No statistical differences were detected between 1995 and 2002 for any of the four habitats tested: low marsh (p=0.23), high marsh (p=0.10),shrubs (p= 0.29),shores and flats (p= 0.38) (Tables 4,5) All test results are included in Appendix E-1.

The changes occurring in GBE are very small as depicted by the graph of percent change of habitat (Figure 5). The percent change is negative depicting an overall loss of all four habitats. To be able to show the minute changes in the habitat maps I have chosen to divide the GBE into its subordinate bay sections so the changes are more easily identifiable. The subsections are labeled Trinity Bay (figure 6), Galveston Bay (figure 7), West Bay (figure 8) and East Bay (figure 9). Maps identifying change in each quad are provided in Appendix C.

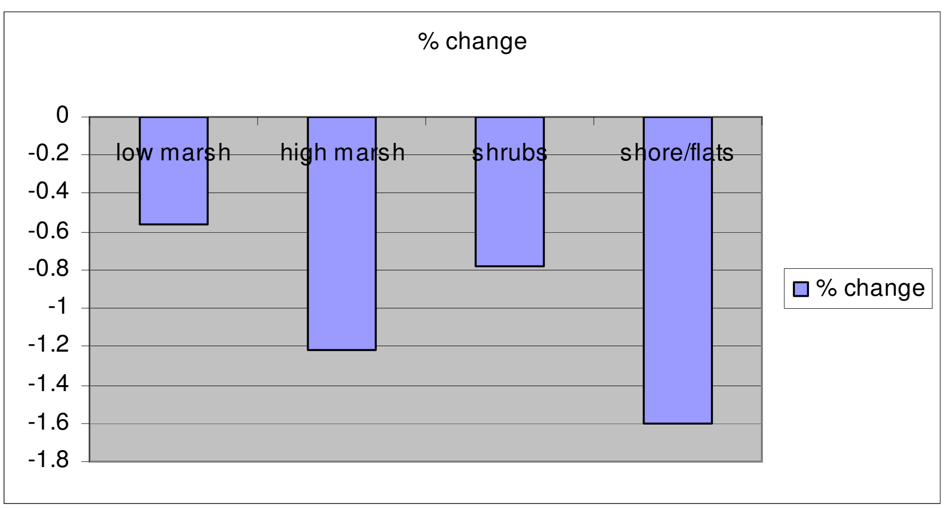

Figure 5: Percent change of estuarine wetland and estuarine and marine shoreline habitats for the GBE between the years 1995 and 2002 Galveston Bay, Texas, USA.

Beginning with Trinity Bay, which contained seven quads (Anahuac, Cove, Highlands, LaPorte, Morgans Point, Oak Island, and Umbrella Point), there was a total loss of wetland and/or shore habitat in two of the seven quads (Figure 6). High marshes (E2EM1P) were lost in Anahuac, Cove, Highlands, Morgans Point, and Umbrella Point quads. Highlands lost the most wetlands; however, it gained the most unconsolidated shore and flat area due to dredge material being added to an active dredge containment site. Shore habitats showed a gain in all but two quads, Laporte and Oak Island. However, these two quads gained wetland habitat in the form of low marsh (E2EM1N).

For the Galveston Bay section (Figure 7) that includes Bacliff, Dickinson, Galveston, Hitchcock, League City, Port Bolivar, Smith Point, The Jetties, Texas City, and Virginia Point, nine quads lost estuarine or marine habitat. The Galveston quad lost the most acreage of estuarine and marine wetland and shore habitats. Bacliff gained 1.4 acres of combined wetland and shore habitat, only losing a small amount of shrub habitat. Dickinson, Galveston, Hitchcock, Smith Point, Texas City lost low marsh. However, Virginia Point, the Jetties, Port Bolivar, League City gained low marsh. All quads except Bacliff lost unconsolidated shore. Galveston, Port Bolivar, and Bacliff gained some high marsh, with Galveston gaining the most at 40 acres.

In the East Bay portion (Figure 8), including High Island, Stanislind Reservoir, Oyster Bayou, Frozen Point, Flake, Caplen, and Lake Stephenson, two quads lost estuarine and marine wetland and shore habitats, two quads had no change, and three quads gained estuarine and /or marine habitats. Flake had the highest amount of loss at 187.4 acres. Frozen Point also lost 103.4 acres of wetlands, however they gained 19.9 acres of shoreline/ flat habitat. High Island gained the most acres of habitat over the seven-year period totaling 92.8 acres shore and low marsh. Caplen and Lake Stephenson also gained low marsh 4.3 acres and 4.9 acres respectively. Caplen gained shore (+36.3 acres) and lost high marsh (-9.8 acres) while Lake Stephenson lost shore (-19.1 acres) and gained high marsh (+15.9 acres). Oyster Bayou and Stanislind Reservoir remained the same.

Finally, in the West Bay section (Figure 9), containing Sea Isles, San Luis, Lake Como, Christmas Point, Oyster Creek, and Hoskins Mound, all but one quad had a loss of estuarine wetlands and estuarine and marine unconsolidated shores and flats. Christmas Point had the most loss of wetlands and shore/flats followed by Sea Isles, losing 262 acres low marsh and shrub wetlands and 321.9 acres of shore and flat habitats. Hoskins Mound lost wetlands and shore and Lake Como lost wetlands. San Luis and Sea Isle gained some high marsh acreage. Lake Como gained 38.5 acres of shore/flat habitats. Oyster Creek remained the same. There is a map of changes for the whole Galveston Bay Estuary included in Appendix C.

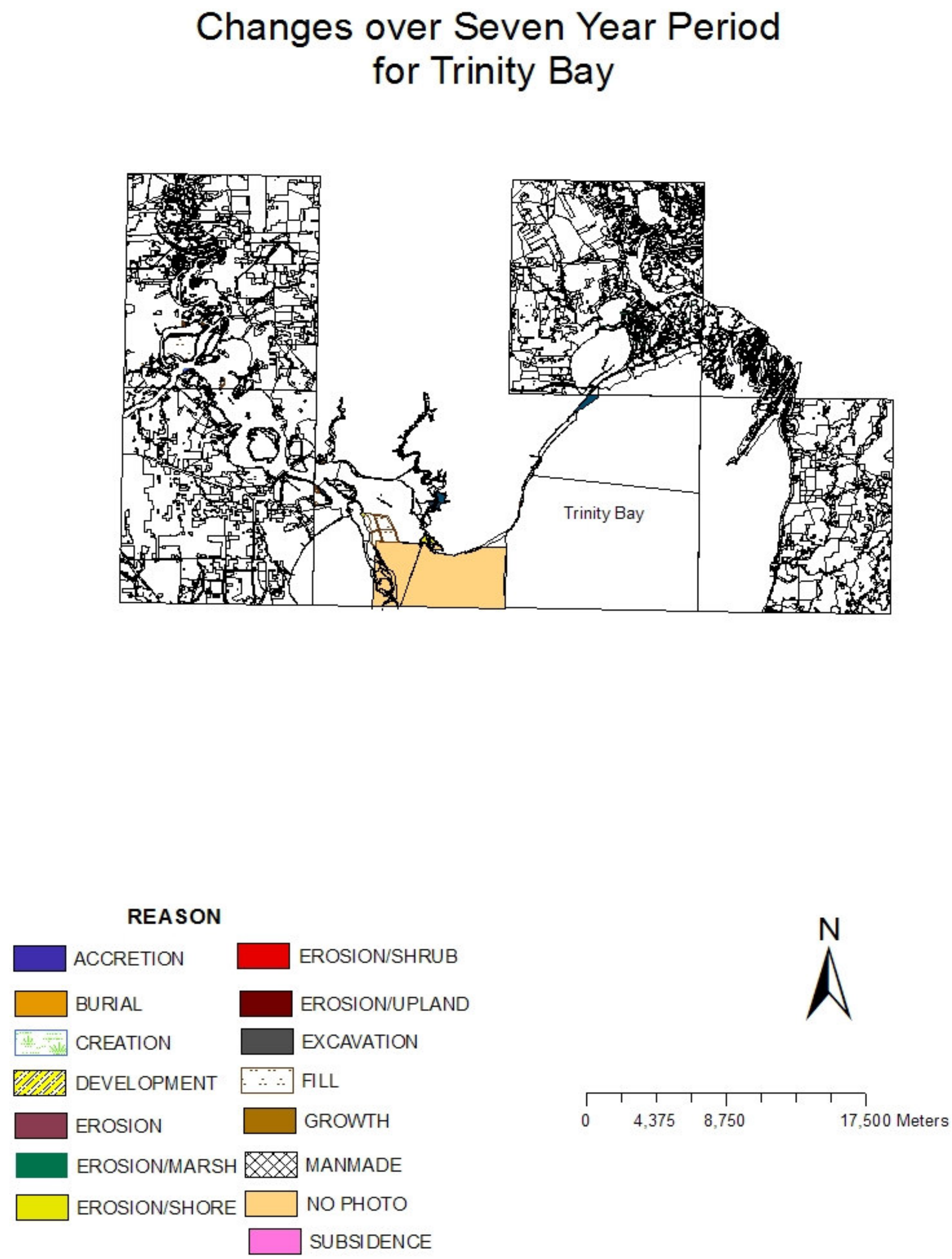

Figure 6: Changes in the Trinity Bay portion of Galveston Bay Estuary (Highlands, Cove, Anahuac, Laporte, Morgans Point, Umbrella Point, and Oak Island) of the Galveston Bay System from 1995-2002.

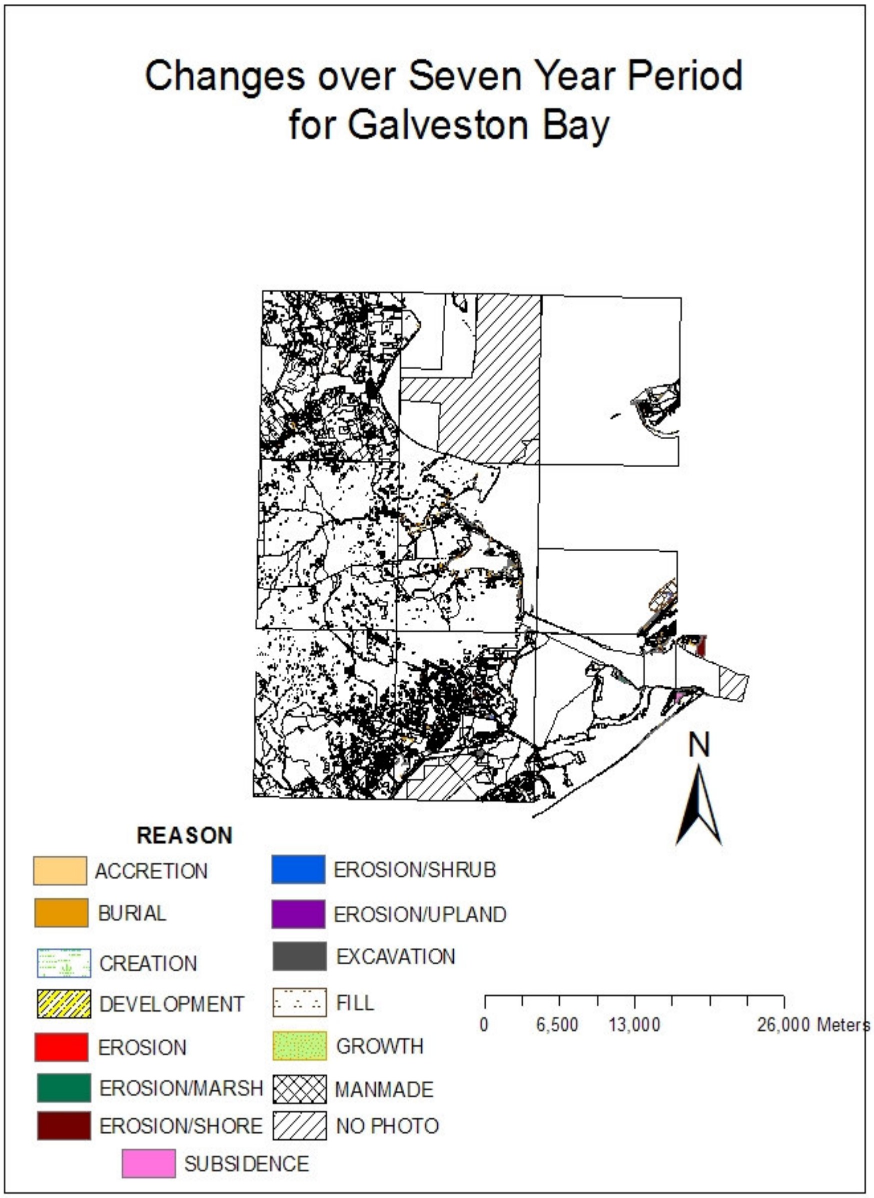

Figure 7: Map of the changes for Galveston Bay portion of the Galveston Bay Estuary (League City, Bacliff, Smith Point, Dickinson, Texas City, Port Bolivar, Hitchcock, Virginia Point, Galveston, and the Jetties) from 1995-2002.

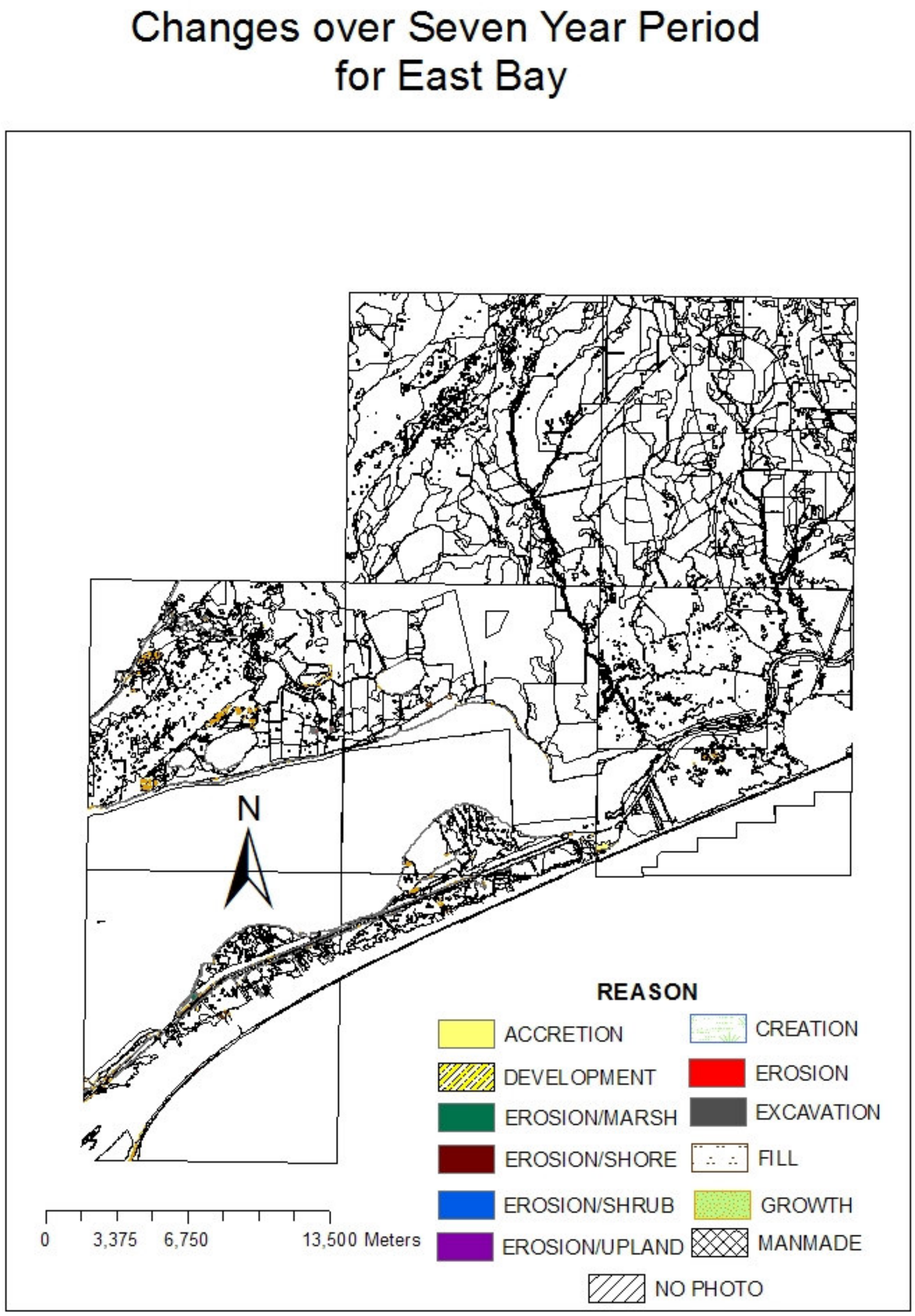

Figure 8: Map of changes for East Bay portion of Galveston Bay Estuary (Caplen, Flake, Frozen Point, High Island, Lake Stephenson, Stanislind Reservoir, and Oyster Bayou) from 1995- 2002.

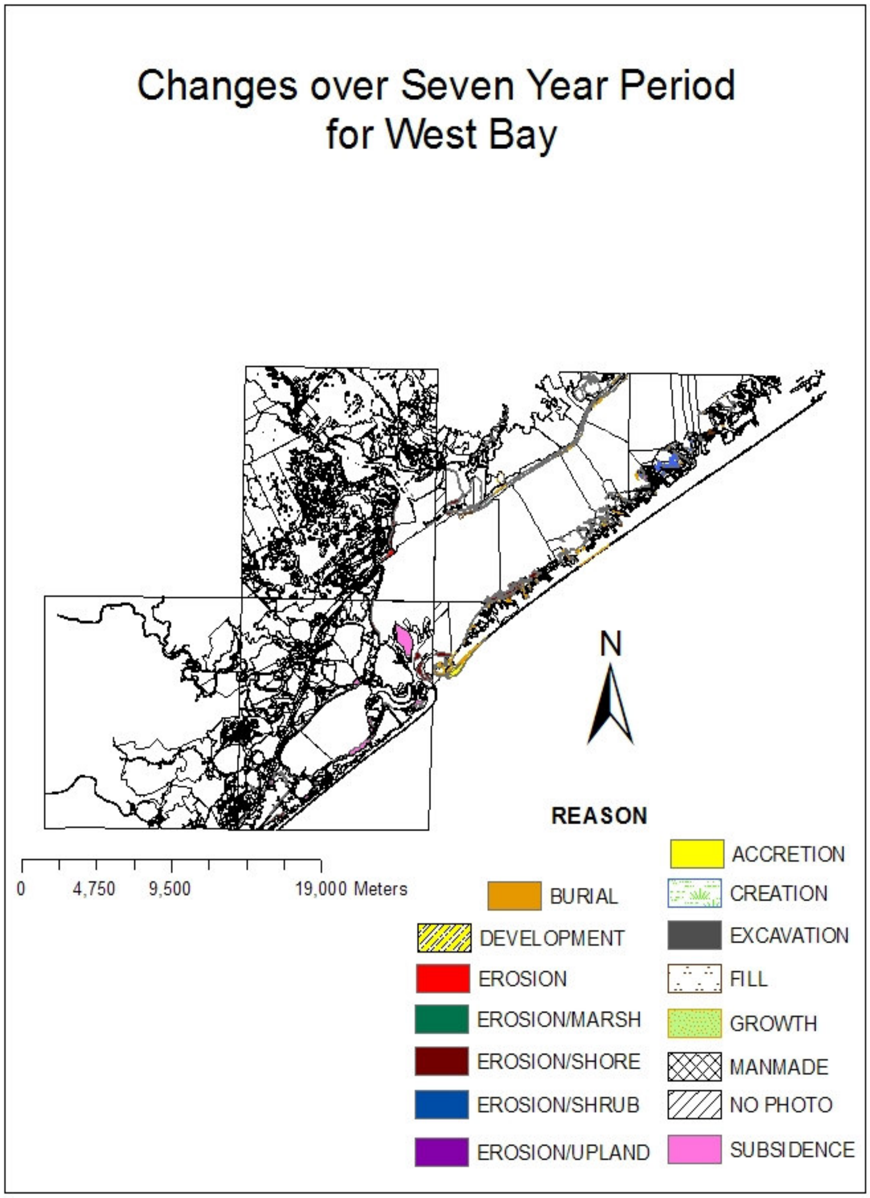

Figure 9: Changes in habitat for West Bay portion of the Galveston Bay Estuary (Oyster Creek, Christmas Point, San Luis, Hoskins Mound, Sea Isle, Lake Como quads) from 1995-2002.

The following table shows the amount of change for each habitat identified in the thirty quads as well as total changes for the quads (Table 6). There was a total loss of estuarine and marine wetlands and unconsolidated shores and flats in the amount of 1,539.9 acres between the years 1995 and 2002. There were losses in all four categories. Shore/flats and wetland habitats lost 352.8, and 1,165.1 acres respectively. The greatest amount of wetland loss was in the high marsh habitat.

Table 6: Acreage of change for wetland and unconsolidated estuarine and marine habitats from 1995 to 2002 per quad in the Galveston Bay Estuary, Texas.

	LOW MARSH	HIGH MARSH	SHRUBS/TREES	SHORE/FLATS	TOTAL
ANAHUAC	25.8	-0.1	0.0	32.8	58.4
BACLIFF	1.2	0.4	-3.0	2.9	1.4
CAPLEN	4.3	-9.8	0.0	35.2	29.7
CHRISTMAS POINT	-26.2	-0.9	-3.6	-564.4	-595.0
COVE	6.5	-29.7	0.3	7.7	-15.2
DICKINSON	-0.1	0.3	0.0	-10.2	-10.0
FLAKE	-71.0	-33.8	0.0	-82.6	-187.4
FROZEN POINT	-41.0	-33.4	0.0	19.9	-54.5
GALVESTON	-88.6	40.8	-3.0	-223.5	-274.3
HIGHLANDS	4.8	-656.2	0.5	632.5	-18.4
HIGH ISLAND	50.7	-11.9	0.0	54.0	92.8
HITCHCOCK	-1.7	-16.7	0.0	-1.8	-20.2
HOSKINS MOUND	-9.3	-0.3	0.0	-108.7	-118.2
LAKE COMO	-43.8	-3.0	-13.5	38.5	-21.8
LAKE STEPHENSON	4.9	15.9	-0.4	-21.7	-1.2
LAPORTE	41.1	0.0	0.0	-24.4	16.7
LEAGUE CITY	23.5	-8.4	-3.9	-26.2	-15.0
MORGANS POINT	-12.9	-5.6	-3.3	585.4	563.6
OAK ISLAND	-3.7	21.4	0.0	-7.4	10.3
OYSTER BAYOU	0.0	0.0	0.0	0.0	0.0
OYSTER CREEK	0.0	0.0	0.0	0.0	0.0
PORT BOLIVAR	31.4	0.9	0.0	-53.0	-20.7
SAN LUIS	-35.6	33.8	0.0	-4.6	-6.5
SEA ISLE	-258.2	12.7	-4.6	-321.9	-571.9
SMITH POINT	-6.3	-2.0	-4.1	-30.2	-42.6
STANISLIND RESERVOIR	0.0	0.0	0.0	0.0	0.0
TEXAS CITY	-12.6	-29.8	-1.5	-1.1	-45.1
THE JETTIES	138.4	-57.0	1.3	-301.5	-218.8
UMBRELLA POINT	1.6	-2.0	0.2	124.8	124.7
VIRGINIA POINT	23.8	-100.2	1.2	-103.3	-178.5
TOTAL	-253.1	-874.6	-37.4	-352.8	-1518.0

There were ten different types of change identified in the reasons field on the attribute table of each of the quads. Table 7 shows the acreage amount per quad for each of these change types. The MANOVA showed no change between quads (P= .055) and significant differences between change types identified (P=.001). The data and analysis for this test can be found in Appendix E-2. The SNK showed that there was more erosion/shore than erosion/shrub, development, creation, excavation, burial, erosion (not resulting in habitat change), and erosion/upland. However, erosion/shore was not significantly different from manmade, accretion, growth, subsidence, erosion/marsh, or fill. The following categories were not significantly different according to the S-N-K: erosion/shrub, development, creation, excavation, burial, erosion, erosion/upland, manmade, accretion, growth, subsidence, erosion/marsh, and fill. The data and results of the SNK are provided in Appendix E-3.

Data comparing the 1995 maps to the 1993 maps created by NWI (National Wetlands Inventory) show a 70.75% habitat change due to label changes (Appendix E-4). A paired t-test, utilizing 120 of the polygons from the previous comparison, was used to determine if there is a difference in acreage of the polygons sampled from the 1993 and 1995 maps; there were distinct differences between years (P-value = 0.008). Boundary shifts ranged from 0.4m to 110.9m with the average being 30.2m.

Table 7: Total change in acres separated by type for each of the thirty quads circa Galveston Bay Estuary, Texas 2002

	ACCRETION	BURIAL	CREATION	DEVELOP -MENT	EROSION	EROSION /MARSH	EROSION / SHORE	EROSION /UPLAND	EX-CAVATION	FILL	GROWTH	MAN-MADE	SUB-SIDENCE	NO PHOTO
ANAHUAC	58.2	0.0	0.0	0.0	0.0	82.4	2.2	0.0	0.0	0.0	126.6	0.0	0.0	0.0
BACLIFF	0.1	0.1	0.0	0.0	0.0	3.4	1.7	7.0	0.0	3.3	2.4	2.6	4.1	26275.1
CAPLEN	32.5	0.0	0.0	0.0	2.4	22.4	3.1	0.1	0.0	0.0	16.7	0.0	0.0	0.0
CHRISTMAS POINT	0.0	0.0	0.0	0.0	0.0	13.6	396.0	0.2	0.0	0.0	0.9	0.0	752.7	0.0
COVE	0.0	1.2	0.0	0.0	0.1	68.0	0.4	0.0	0.0	0.0	45.5	0.0	1.1	0.0
DICKINSON	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.6	0.6	0.3	0.1	29.2	0.0
FLAKE	44.5	0.0	2.2	0.0	5.6	108.6	76.7	0.1	35.8	14.6	51.4	2.1	0.0	75.1
FROZEN POINT	22.3	0.0	0.8	0.0	0.0	71.5	6.1	0.0	0.0	15.9	11.4	0.0	0.0	96.8
GALVESTON	33.1	51.8	0.0	19.0	31.9	93.8	201.9	25.9	1.7	1.1	52.7	10.9	1.2	0.0
HIGHLANDS	1.3	0.0	10.2	0.0	9.9	6.2	19.2	0.4	1.9	669.8	0.1	5.8	2.2	0.0
HIGH ISLAND	66.6	0.0	0.0	0.1	1.8	15.1	0.4	0.0	0.0	0.2	56.1	0.0	0.0	0.0
HITCHCOCK	0.0	0.0	0.0	0.0	0.4	1.7	4.9	1.6	0.0	0.0	0.0	48.9	0.0	1526.1
HOSKINS MOUND	0.0	0.0	0.0	0.0	0.0	9.5	167.2	0.8	0.0	0.0	0.0	0.0	0.0	0.0
LAKE COMO	30.0	0.1	37.0	4.8	0.0	45.8	1.3	0.0	13.2	12.8	12.0	5.3	26.1	0.0
LAKE STEPHENSON	0.0	0.0	0.0	0.0	0.0	61.3	27.0	18.7	0.0	0.0	86.4	0.8	0.0	16.4
LAPORTE	44.4	0.0	0.0	0.0	0.3	0.9	28.2	15.5	0.0	0.0	56.1	0.4	14.2	0.0
LEAGUE CITY	37.4	8.3	0.0	8.0	0.8	22.4	30.4	7.4	46.0	15.4	39.3	1.9	12.8	4.4
MORGANS POINT	179.4	1.0	0.9	2.8	0.0	20.2	229.9	3.2	0.0	778.8	34.8	0.0	0.0	7894.6
OAK ISLAND	0.3	0.0	0.0	0.0	0.0	14.1	0.4	11.7	0.1	0.3	32.0	0.0	0.0	0.0
OYSTER BAYOU	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OYSTER CREEK	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PORT BOLIVAR	13.5	0.0	17.5	0.0	7.4	7.7	52.3	2.2	0.0	135.0	22.3	516.5	0.0	212.2
SAN LUIS	184.6	3.9	0.0	0.0	2.4	27.0	97.9	1.0	0.0	0.0	110.5	0.0	0.0	0.0
SEA ISLE	48.3	37.4	0.0	2.7	6.6	280.4	422.0	40.5	2.8	31.0	48.7	0.0	0.1	888.9
SMITH POINT	3.3	0.6	0.0	4.0	1.8	14.8	34.9	0.1	0.0	0.0	7.6	0.0	0.0	0.5
STANISLIND RESERVOIR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 7: continued

	ACCRETION	BURIAL	CREATION	DEVELOP -MENT	EROSION	EROSION /MARSH	EROSION / SHORE	EROSION /UPLAND	EX-CAVATION	FILL	GROWTH	MAN-MADE	SUB-SIDENCE	NO PHOTO
TEXAS CITY	0.8	5.3	0.2	0.0	0.0	44.8	2.8	0.0	0.0	17.9	23.2	0.0	0.7	0.0
THE JETTIES	28.4	1.8	0.0	0.0	19.8	16.0	308.2	0.6	0.0	0.0	69.4	0.0	145.0	1285.7
UMBRELLA POINT	132.1	0.0	0.0	5.5	0.8	0.0	0.1	0.1	0.0	3.1	1.8	0.0	0.0	0.0
VIRGINIA POINT	10.2	7.5	33.9	1.3	44.8	135.4	108.8	4.9	4.2	33.2	68.1	0.0	39.1	5204.4
TOTAL	971.5	119.0	102.7	48.2	136.8	1187.1	2224.2	142.2	106.3	1732.7	976.4	595.2	1028.6	43480.3

DISCUSSION

Early studies of remote sensing found distinct color patterns for wetland vegetation (Reimold et al 1973). More recent studies have found that using near infrared (NIR) or color infrared (CIR) spectral ranges can discriminate between marsh vegetation species (Artigas and Yang 2006). The photography and resolution (pixel size) used on individual digital photos in this study was 1 x 1 m for NIR photography and 0.25 m resolution for true color photos taken in 2002 for some photos. . Thus, the recognition of habitat and their boundaries was much greater than satellite imagery. The scale of maps produced in this research was 1:24,000 which allows the drawings to overlay 1:24,000 digital quad maps. National Wetland Inventory maps are generally provided on quad maps with NWI symbols and this scale have been commonly used in the National High Altitude Photography and Aerial Photography programs (Johnston and Meysembourg 2002) and can be obtained from the Texas Natural Resource Information System (TNRIS) and U.S. Geological Service.

In this project some areas were not photographed in the 2002 imagery set, and therefore assumptions were made based on previous photos of these areas. A significant amount of the area listed in Table 6 was under the change type listed as “NO PHOTO”; indicating that the 2002 imagery for those polygons was not available. Due to the inability to distinguish changes in these areas, the 1995 habitat labels were copied over for the 2002 habitats assuming no change in these areas not covered by the 2002 imagery. Under the above assumption the “no photo” changes were not included in the MANOVA to determine differences in habitat coverage. The amount of area not examined for change due to no photography could be as much as 2,393.3 acres of wetland and 735.1 acres of shoreline habitat.

Comparing the results of this study to other similar studies of GBE coastal wetland change I found several similarities and differences. According to White (1993), salt and brackish marshes consisted of 108,200 acres in 1989, which was an increase from 1979 of 2,280 acres. According to The State of the Bay (Lester and Gonzalez 2002), Pulich and Hinson (1996) reported 97,934 acres of estuarine wetlands in 1995. Using the 1995 image set, I calculated 116,567 acres of emergent marsh. The increases were likely attributable to changes in land use and channel/ tidal connections to the bay system, increasing saltwater input to some previously isolated wetlands. Prior to 1979, the rate of loss for GBEP was estimated at 405 acres/ yr (White 1993), but after 1995 the rate of emergent loss dropped to about 161 acres/yr. Rates had begun to drop after 1975 in most studies, but errors in map overlay and technique contributed to the reporting of larger loss numbers (White 1993). The technique I used to modify existing digital maps reduces this kind of overlay error and provides a more accurate identification of changes in wetland and shore habitats. Furthermore, cutting habitat polygons from within existing polygons reduced the amount of area being counted under multiple habitats; which was an error found with the NWI maps. According to previous shrub habitat data reports, there was a net gain from 1972 to1984 (445 acres) (Johnston et al 2005) and 1989 (551 acres) (White 1993) these gains are attributed to habitat change from one type to another primarily from palustrine shrub habitat (PSS) to estruarine shrub habitat (ESS). These changes come from changes in the classification because of better analysis and possibly changes in salt water intrusion (White 1993). I calculated a net loss in shrub habitat, decreasing from 1,102 acres in 1995 to 1,094 acres in 2002. Shrub habitats are hard to calculate because of their proximity to upland areas; they often get mislabeled. The loss of this habitat was largely due to development and I believe this is also because of their location and possibly the labeling errors from previous reporting. The losses and gains found above were not limited to any one portion of the GBE; therefore, one can conclude that the trends in habitat change are similar in amount for all portions of GBE.

Areas further south along the Texas coast also show erosion along the Gulf Intracoastal Waterway (GIWW). The area of Mad Island Marsh reported a loss due to erosion of 0.484 km^2 between 1943 and 1991 after the initial creation of the GIWW (Williams 1993). This erosion is reportedly due to wave action from increased shipping traffic in the GIWW. Secondary reasons for the large rate of erosion in this area are increased water depth from dredging activities and the lack of vegetation along the dredge spoil islands, which showed the greatest amount of erosion (Williams 1993). I found similar patterns of erosion around the GBE in high shipping traffic areas of the Houston ship channel and along the GIWW on Bolivar Peninsula, Pelican Island ship channel, and the dredge spoil islands along GIWW in West Bay.

Wetland habitat change in the northern Gulf of Mexico has been studied extensively. The Mississippi River delta area of Louisiana and Lower Mobile Bay experienced marsh habitat reductions of 51% –and 36% from 1956-1979 respectively. In contrast, the estimated decline in GBE was considerably lower (-13%) for the same time period

(Johnston and Ader 1983). This is similar to the low amounts of wetland loss observed from 1995-2002. Care should be taken when comparing estuarine wetland and shoreline changes from Texas to Louisiana because Louisiana's rate of change is 5 times higher than other areas of the Gulf Coast due to differences in geomorphology and the uniqueness of the Mississippi Deltaic System (Shirley and Battaglia 2006). However, it interesting to note that man-made structures along the Louisiana coast, primarily jetties, have caused accelerated erosion in some areas and small rates of accretion in other areas. This is the same kind of accretion seen around the Galveston jetties and erosion along the front of Galveston Island along the seawall and other structures. From 1855 to 2002 the western portion of Louisiana had lower rates of erosion than the eastern portions and that trend seems to continue west into the northern coast of Texas (Penland et al 2005).

Sea level rise, subsidence and accretion rates are important factors in habitat change throughout the Gulf Coast. The Gulf Coastal Plain region of Mississippi is showing vertical accretion at a rate greater than relative sea-level rise (RSLR) (Shirley and Battaglia 2006). In relation to RSLR and subsidence factors, White and Morton (1997) investigated wetland loss along fault lines in Texas coastal wetlands. These faults are in areas of oil and gas production. Faults are visible on aerial photography and the downthrown side of the fault is characterized by changes in hydrology causing greater areas of inundation (White and Morton 1997). This was the characteristic used here to label areas of subsidence in my research, which was approximately 1,029 acres of wetland and shoreline habitat lost to subsidence from 1995 to 2002. According to this study, these areas are occurring from Sabine Lake, northeast of GBE, to the Freeport area, southwest of GBE. This kind of fault movement results in loss of wetlands due to drowning and spread of wetlands into upland areas caused by increased inundation (White and Morton 1997). Subsidence is also related to the human influences on ground water removal. According to the Harris-Galveston Coastal Subsidence District website, the amount of subsidence along the west and northwest side of GBE has decreased. They contribute the decrease to lower volume of groundwater pumping and fluid extraction (www.hgsubsidence.org). The losses of wetland from 1995 to 2002 may reflect the decrease in subsidence when compared to the high subsidence rates that occurred from 1955 to 1979.

Changes in habitat occur due to changes in land use around an area. Shirley and Battaglia (2006) observed that marsh loss in Louisiana and Mississippi resulted in an increase in open water and scrub-shrub from woody encroachment in areas of salt water intrusion. They also found a decrease in agriculture land use at some sites which resulted in an increase in forested habitats (Shirley and Battaglia 2006). Where encroachment, predominately of invasive Chinese tallow (*Sapium sebiferum)*, was present the shrub habitat increased while the marsh habitat decreased (Shirley and Battaglia 2006). This species is widely distributed and fast growing, we have seen similar changes in GBE causing the change from shrub to forested habitat (White et al 1993). This demonstrates that changes within a system can have a profound affect on all habitats observed in that system. In other areas marsh was converted to open water this loss is attributed to increase in the number and size of canals. This change is similar to increased canals in residential developments and recreational areas of GBE. Other changes described by Shirley and Battaglia (2006) were successional changes as the edge migrated and salt water intrusion increased. Similar changes occurred in GBE, as high marsh shifted to low marsh or marsh vegetation spread to previously unvegetated flats. As the amount of structures (ie roads, breakwater, and residential areas) increased, succession of vegetation was limited (Shirley and Battaglia 2006). This was also noticed around the GBE along roadways, bulkheads, and other developed areas. The structures prevent spread of marsh vegetation because of increases in elevation or physical blocks to marsh spread.

From 1956-1978 Louisiana lost ~661,700 acres of coastal wetland, which is a rate of 30,000 acres/ yr. This rate decreased to 24,203 acres/yr between 1978 and 1990. Coastal marshes around Mobile Bay, Alabama decreased at a rate of 416 acres/yr from 1955 to 1979. Habitat maps in 1988 show no loss of wetland in Mobile Bay from 1979 to 1988. Local losses appear to be offset by emergent growth in existing spoil containment areas (Johnston et. al 2005). A study of Tampa Bay, Florida showed marshes declined by 52 acres/yr from the 1950's to 1982 and mangroves declined 49 acres/ yr for the same time period (Johnston et al 2005). With the exception of Mobile Bay, Alabama, the other locations including GBE lost wetlands at rates lower than previously reported for those same locations. GBE and Tampa Bay, Florida both lost wetlands at a comparable rate. The reduction in losses were attributable to increased regulatory efforts, continued reporting of status and trends and public awareness of the benefits of these crucial habitats. The information from Mobile Bay, Alabama from1988 show how significant changes in wetlands within dredge spoil containment sites can be when reporting changes. This implication is also seen in the Highland quad of the GBE; where there was a large loss of wetlands due to recent activity at a dredge spoil containment site. Dredging activity can bury existing plants; increase elevations in open water which allows wetland plants to colonize, or increase elevations above so that marsh plants can not grow.

Nationally, wetland change trends are a net loss of habitat; however, the rate of emergent wetlands loss appears to be decreasing annually (Kent and Mast 2005). This corresponds to the patterns of wetlands loss found by Kent and Mast (2005) in San Dieguito Lagoon, California and Kentula, Gwin, and Pierson (2004) in freshwater wetlands in the Portland, Oregon area. This pattern is also similar to the minimal loss documented for the estuarine wetlands in this study of the Galveston Bay Estuary. The San Dieguito study reported a 6% (15.12 ha) loss of study site wetlands from 1975-1994, which is .8 ha/yr (Kent and Mast 2005). In the Portland study of small urban freshwater wetlands, there was a 6% loss from 1992-1998 (Kentula, Gwin, & Pierson 2004). While this study focused on freshwater wetlands, it reported a similar decrease in the rate of loss of wetlands for an increasing populated area of the country. It also suggests that with increased public information and awareness of the importance of wetlands these habitats can be protected. There are two suggestions as to why there is a decrease in the overall amount of loss. The first reason is that the total amount of wetland habitats remaining is so much less there are not many wetlands to lose. The second reason is the increase in protective legislation since the 1970’s (Kent and Mast, 2005).

The most important pieces of legislation providing protection to wetlands are the National Environmental Policy Act of 1969 (NEPA) and section 404 of the Clean Water Act. With the creation of this legislation there was a government agency (USACE) instructed to oversee and enforce the permitting process for dredge and fill activities. I believe these and subsequent cases and rulings contribute to the protection of wetlands. The laws make it illegal to alter tidally influenced estuarine habitats.

The existing wetlands legislation and related permit procedures require compensatory mitigation for wetland loss. This mitigation can at times produce a local increase in wetland amount. One study on mitigation in Indiana showed that there were 34.33 ha required for the mitigation of 13.73 ha of lost wetlands and other navigable waters. Of the created mitigation sites 15.21 ha had established, creating a net gain of wetland habitat (Robb 2002). This study and other studies of mitigation effectiveness have stated that many of the required compensatory mitigation sites are not created or do not establish properly (Robb 2002).

While this study did not specifically examine required mitigation for the GBE, it did note that created wetlands offset loss in the GBE. While the number of permitted changes requiring mitigation during the period of this study was unknown, there was a reported 102.7 acres of created wetland habitat between 1995 and 2002. Without these creation sites the amount of wetland loss for GBE would be nearly double that which was reported. There is much work on created versus natural marsh quality differences; so to determine if these types of differences are affecting the GBE it may be important to know what percentage of the existing wetlands in 2002 were created versus naturally occurring. In 2002, there were 44,568.4 acres of E2EM1N (low marsh) of which 102.7 acres are labeled as created. This is equal to 0.23% of the low marsh wetlands being created after 1995. I do not believe that the ecological functions of the marsh or the quality of marsh habitat in the GBE are greatly altered by this percentage of created marsh habitat.

According to The State of the Bay publication of the Galveston Bay Estuary Program (Lester and Gonzalez 2002), 17 restorations or marsh creation projects were planned from 1995 to 2000 for a total of 228,118.15 acres of new marsh habitat. The discrepancies in the amounts of created marsh could be due to timing; some of these areas could not be completed or planted at the time the aerial photography was taken. Some of the restorations or creation projects could have failed to establish wetland vegetation. The possible discrepancies are commonly noted in other studies of mitigation effectiveness. A common reason for mitigation or creation failure is the inability of agencies to continuously monitor for success criteria; therefore, monitoring is limited to 5 years or not monitored at all (Robb 2002). There is also a high possibility that some of the wetlands created were not in a distinguishable pattern; therefore they were not labeled as created on the maps.

SUMMARY

Summary

In summary, I believe the method of altering 1995 maps and overlaying the 1995 drawings on 2002 imagery to create new 2002 maps and determine changes worked well and was needed because of the differences between the 1995 and 2002 maps. There was not a significant loss of wetland or shoreline habitats from1995 to 2002. There was not a significant difference in the amount of changes between quads around the Galveston Bay Estuary. There were significant differences between the types of changes. The most significant difference was the amount of unconsolidated shore erosion compared to the other categories. Also development, excavation, and burial from washover events created minimal amounts of change to wetland habitats.

Future Considerations

I hope this project helps us to explore how we can map and categorize areas that are hard to reach since they are privately owned or occur in shallow wet habitats that are hard to reach. Also, money for rigorous ground-truthing is generally lacking. The maps that were created for this project are available in digital format and can be used as a base for future change determinations. These maps can also be used as tools for other agencies and organizations to make informed decision and estimates of the amount and types of wetlands in an area. These maps were created in conjunction with a study of wetland change due to development of both estuarine and palustrine wetlands by the Galveston Bay Estuary Program (GBEP), therefore these data files are available as shape files to be added and edited in future GBE status and trend reports. As a community of researchers we need to work on a system to share and update information regularly. It may also be necessary to field verify vegetation and salinity measurements to ensure proper habitat classification. While the trend seems to be moving toward less loss of estuarine wetlands, we still need to keep up with advances in protection and creation. Creation projects can be mapped from permit data, GPS point, as well as aerial photography to better track mitigation and creation success, in the future. The services these wetlands provide is still being studied and we may never fully understand all the intricate details of such complex and dynamic systems.

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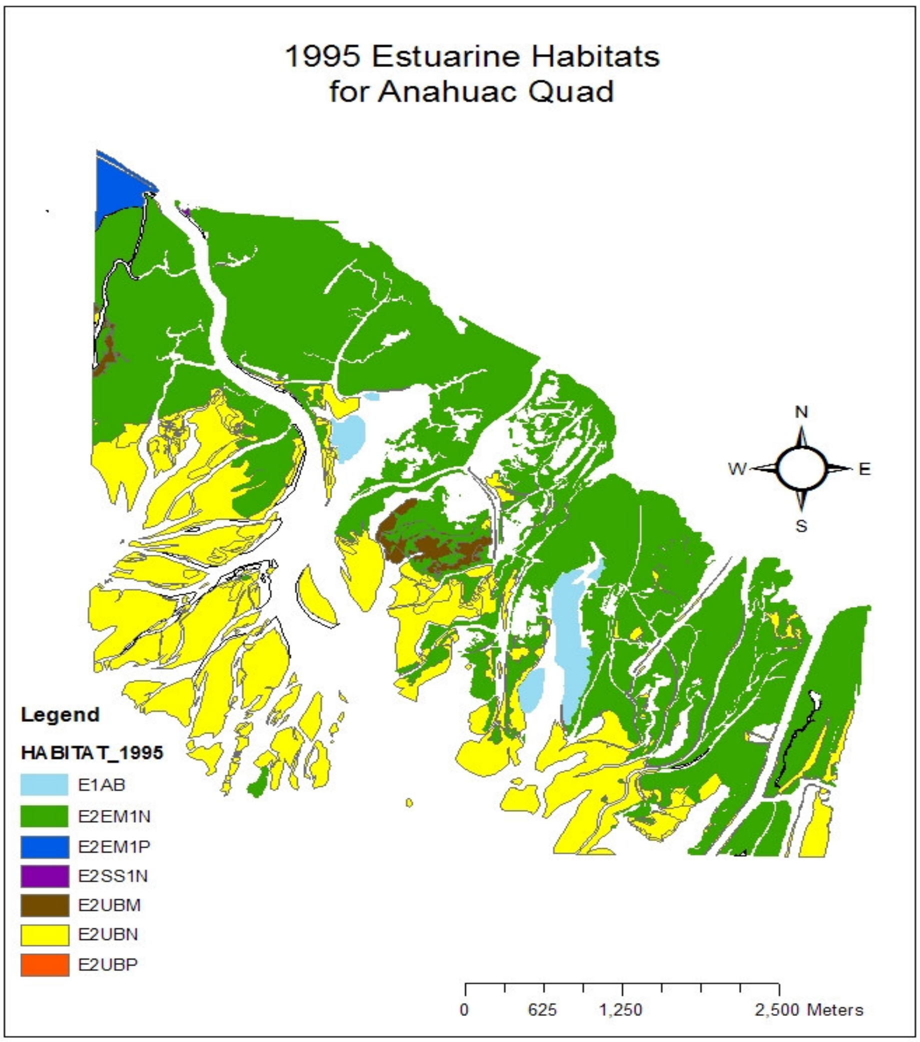
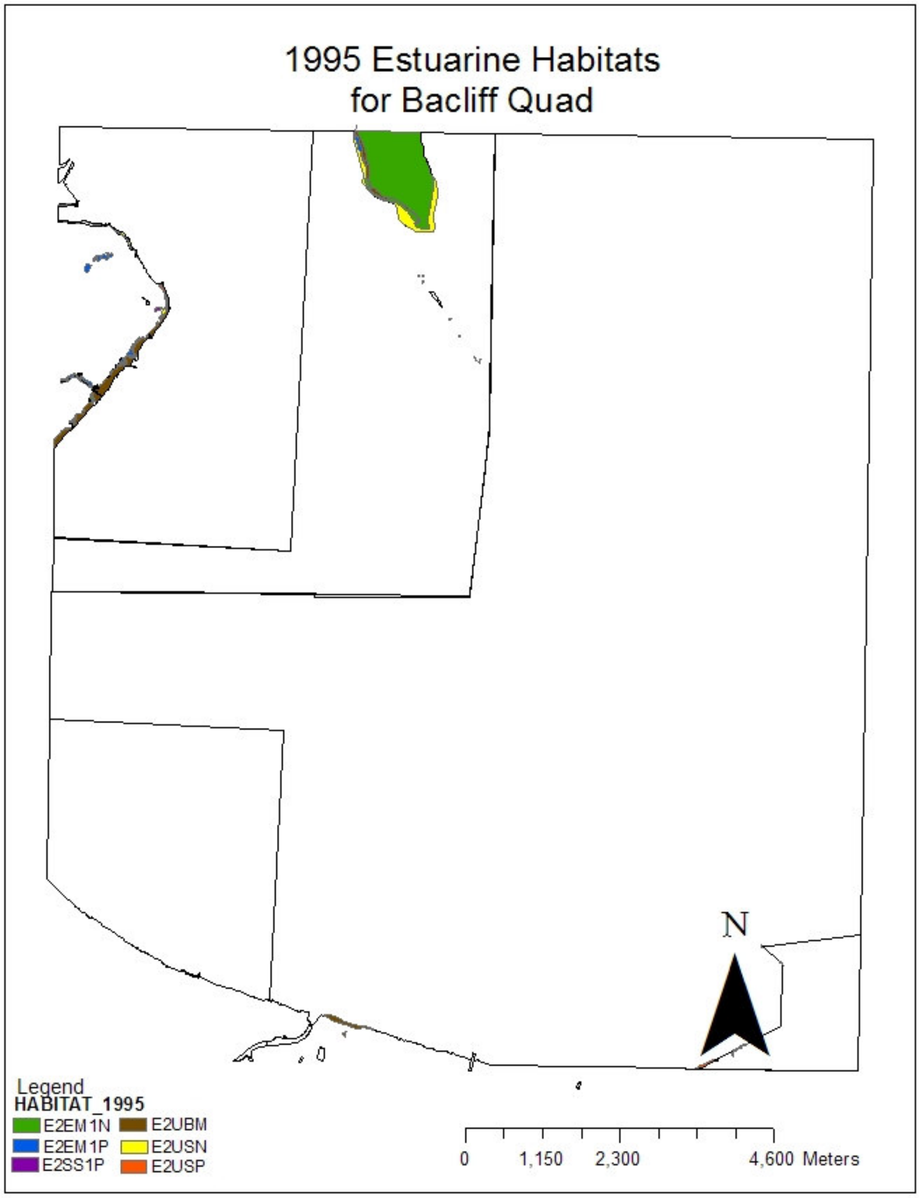
APPENDIX A

MAPS OF MARINE AND ESTUARINE HABITATS FOR EACH INDEPENDENT QUAD PRESENT IN 1995

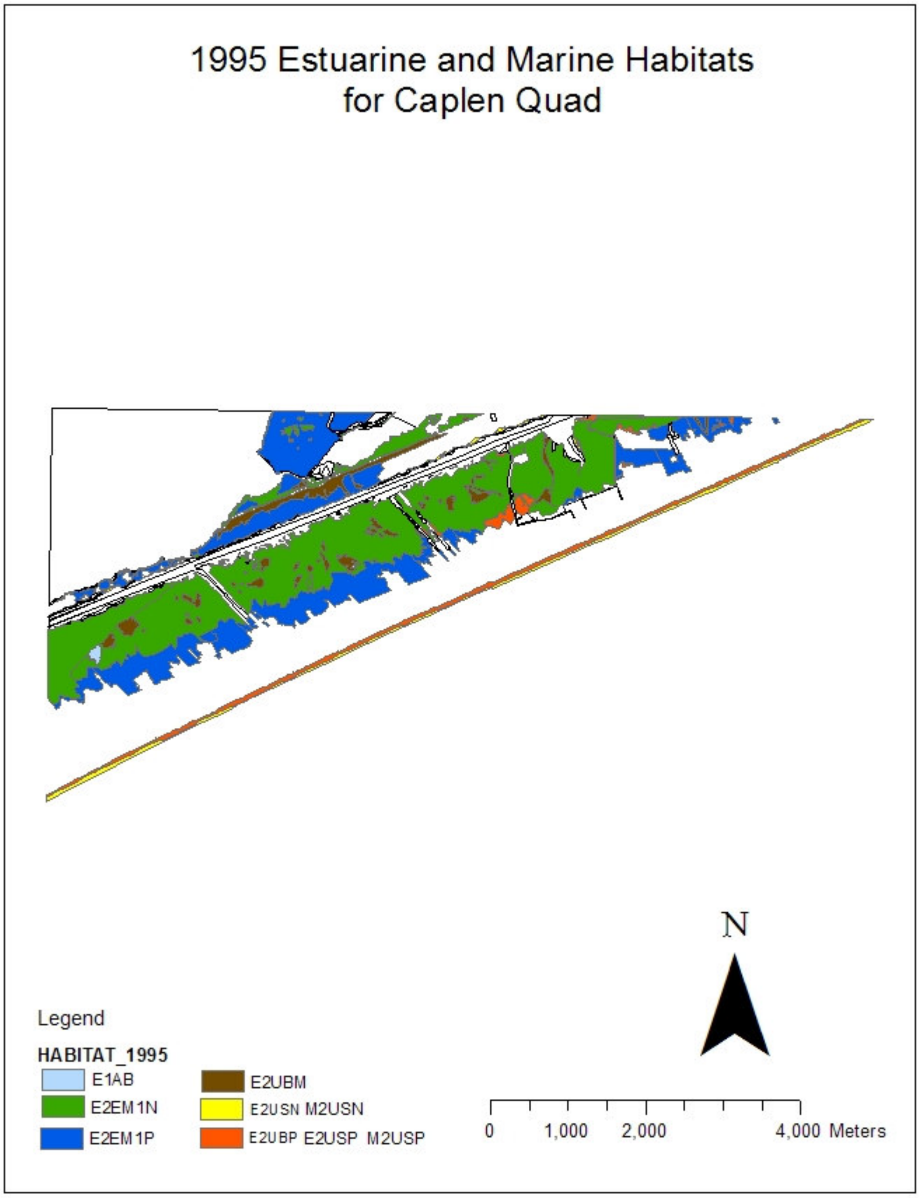
A-1: Anahuac quad map



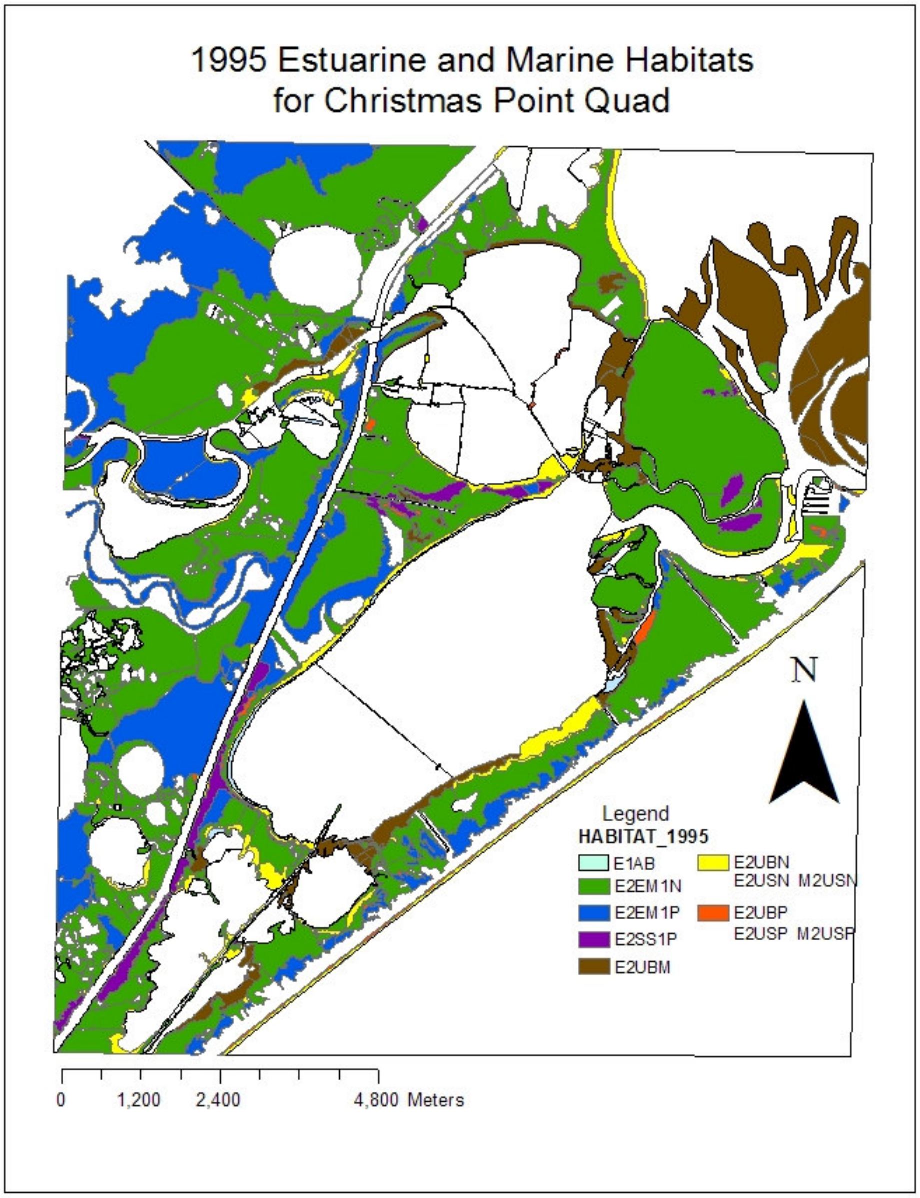
A-2 Bacliff quad map



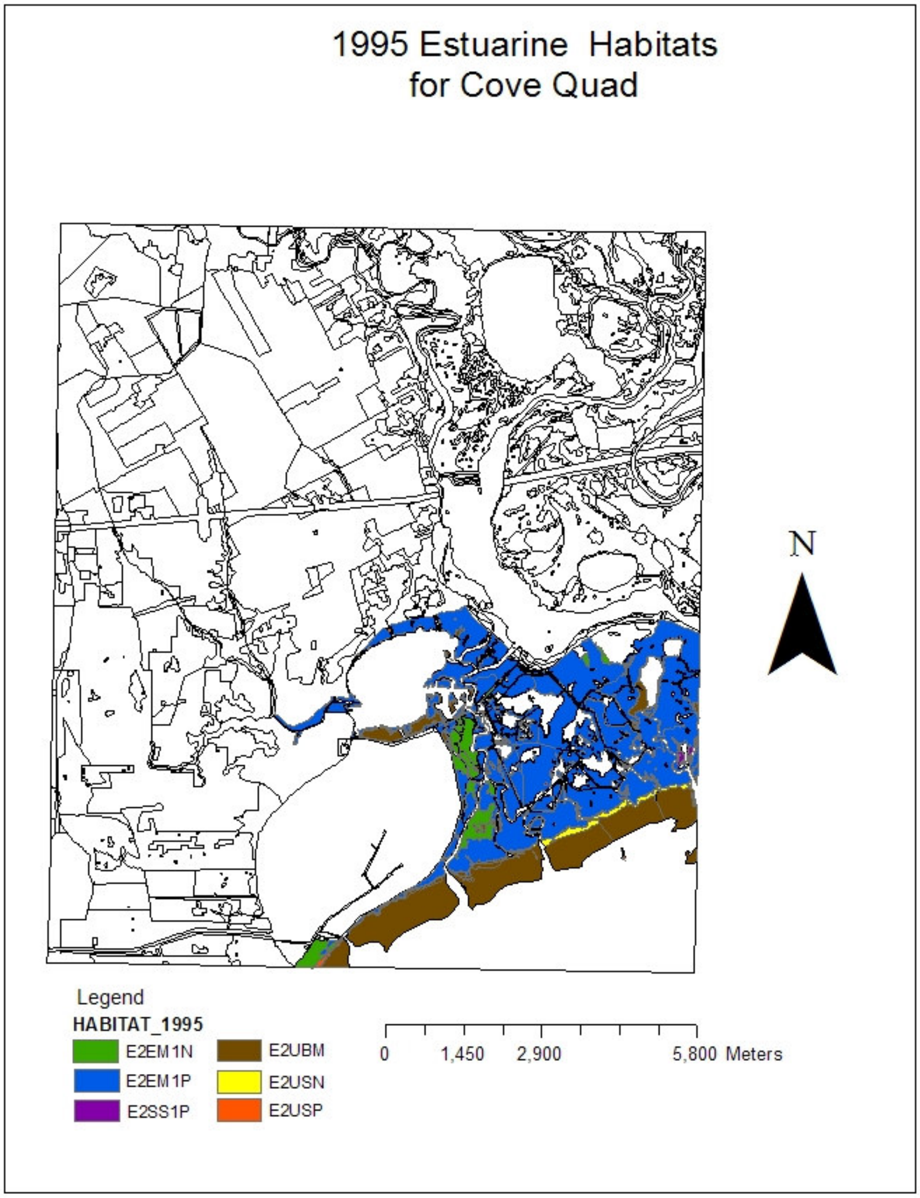
A-3: Caplen quad map



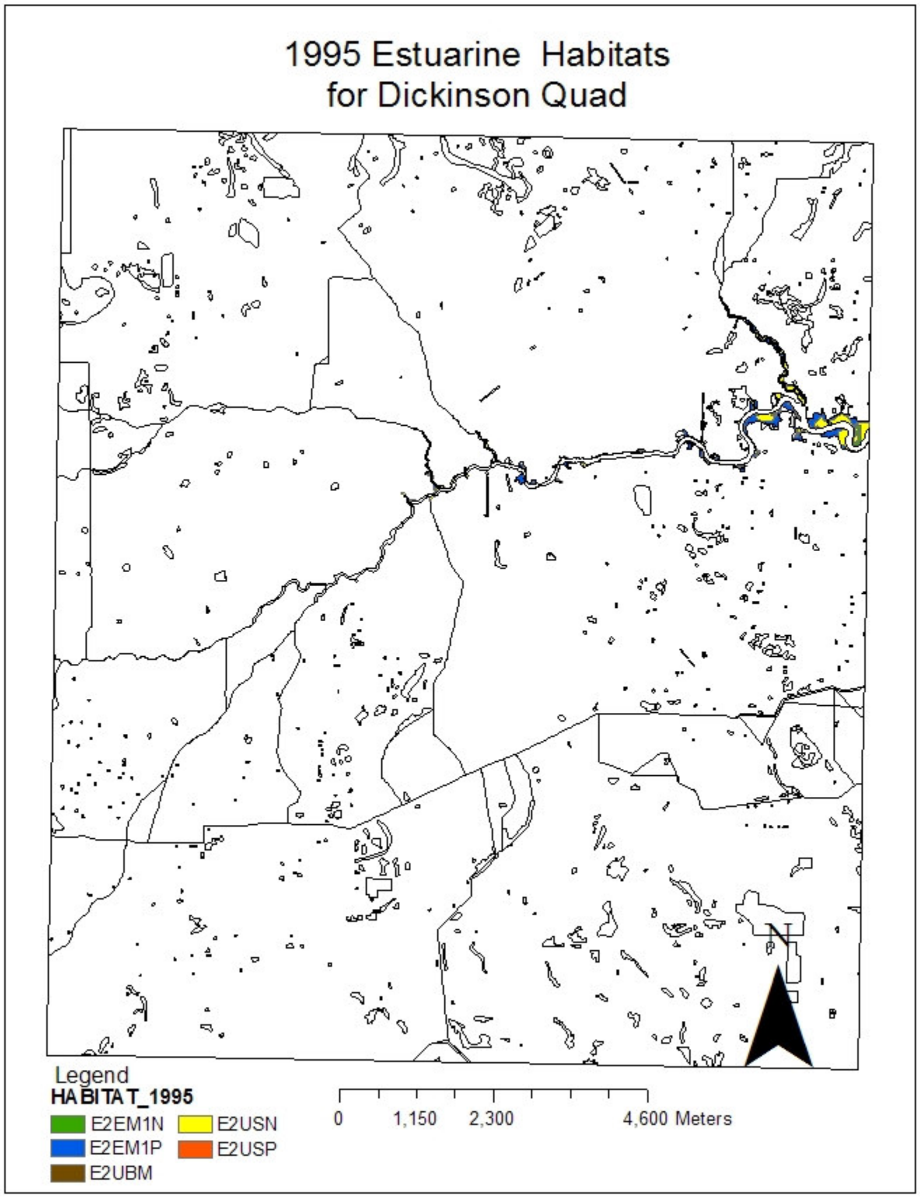
A-4: Christmas Point quad map



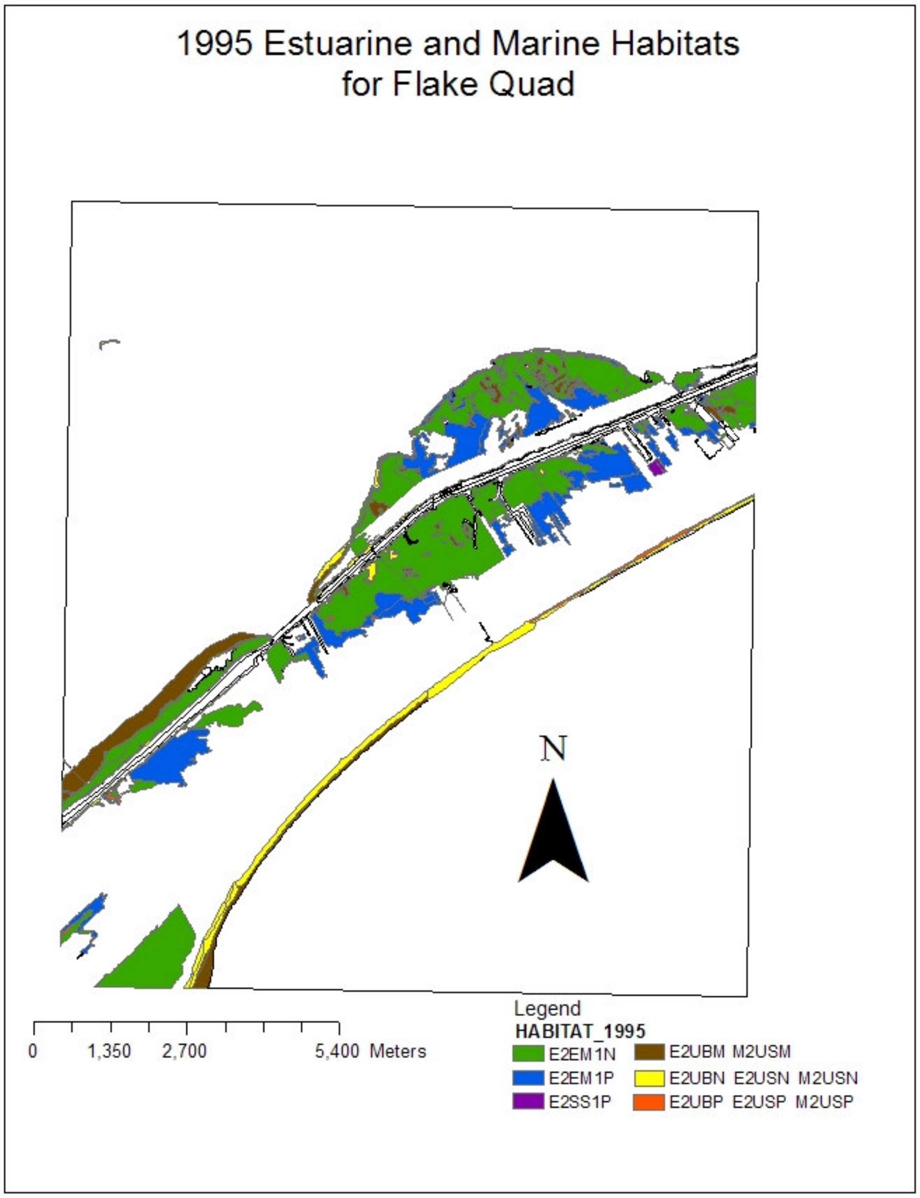
A-5: Cove quad map



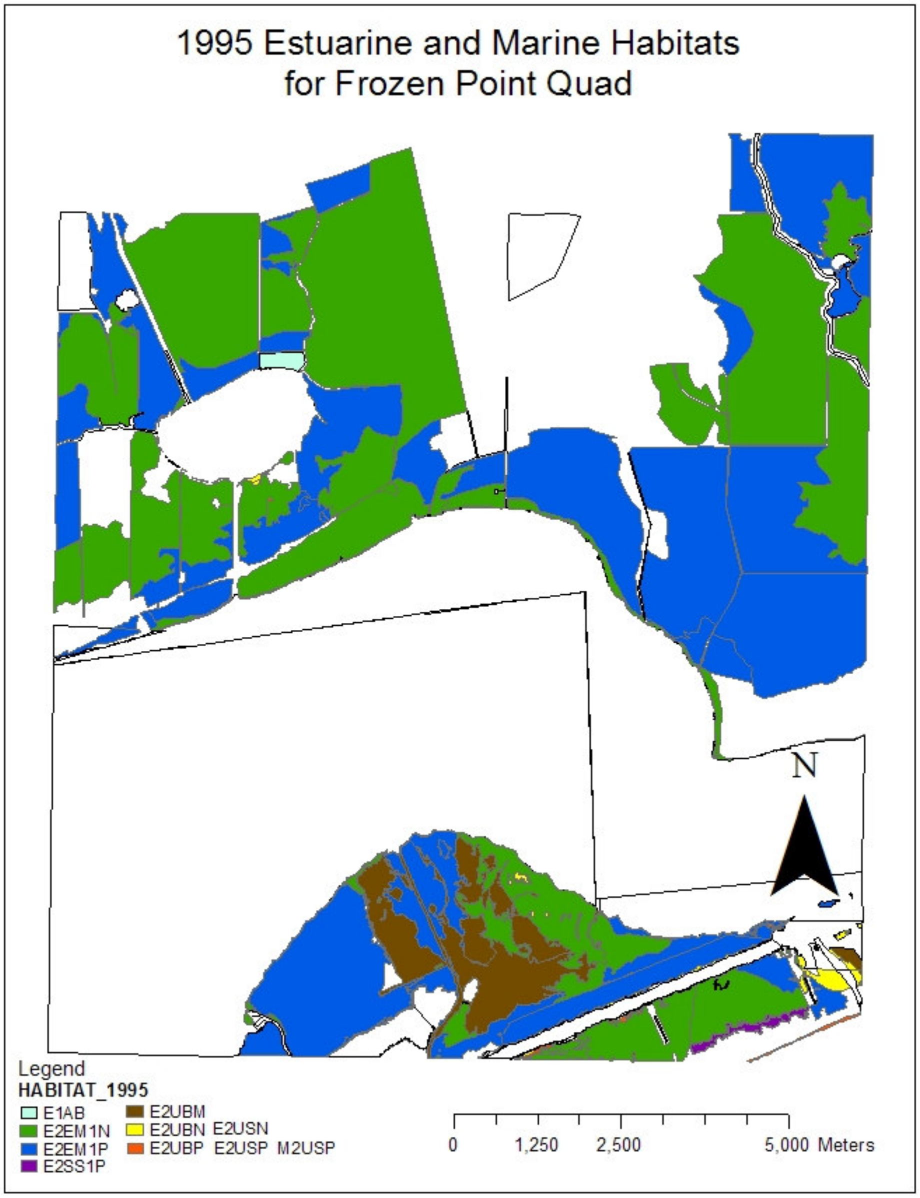
A-6: Dickinson quad map



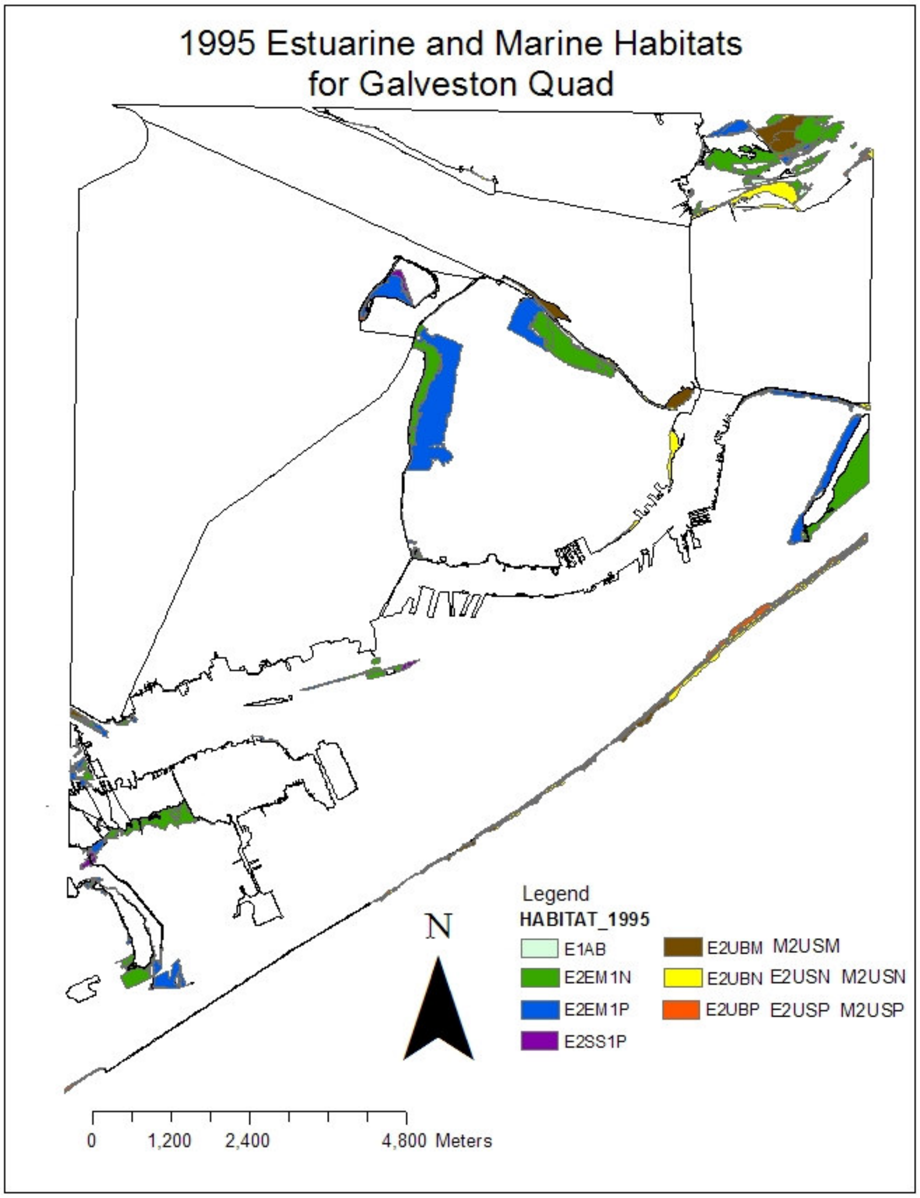
A-7: Flake quad map



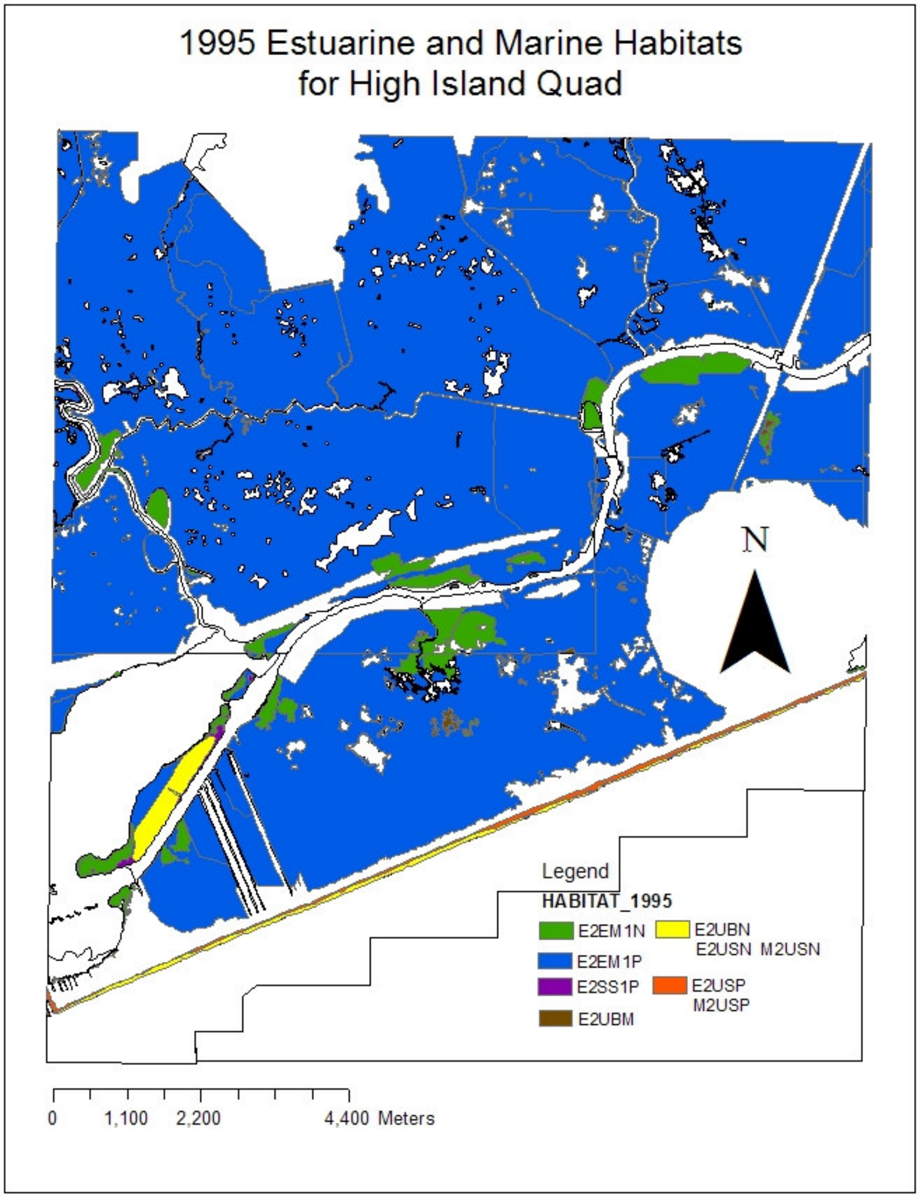
A-8: Frozen Point quad map



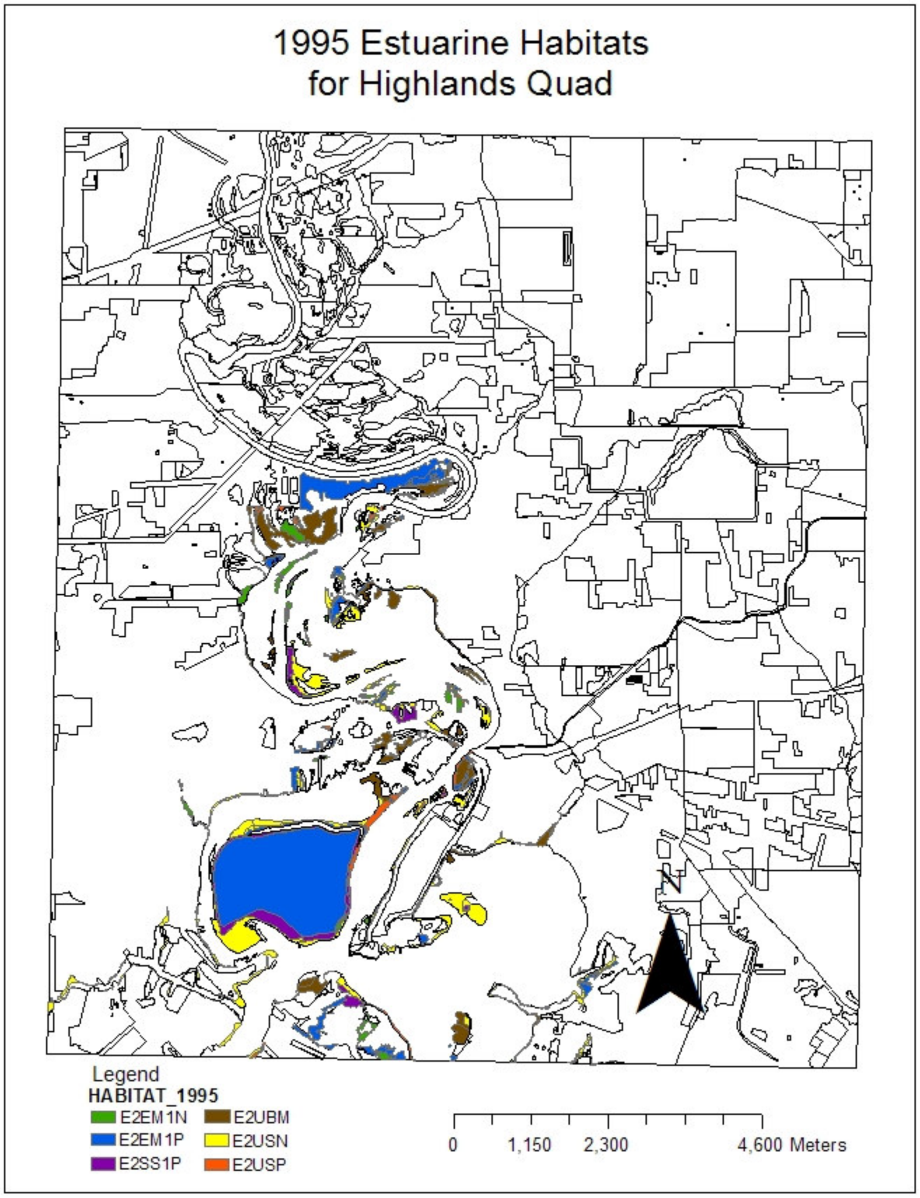
A-9: Galveston quad map



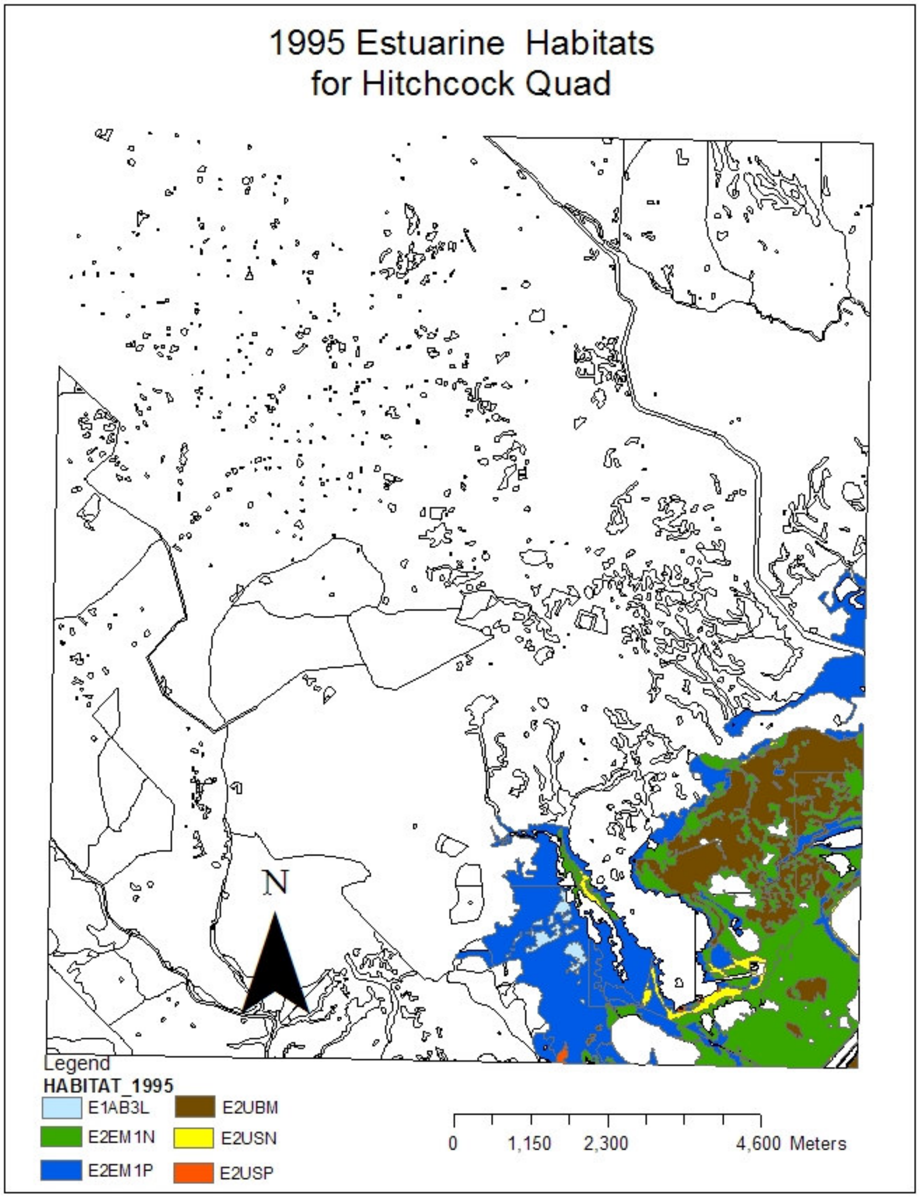
A-10: High Island quad map



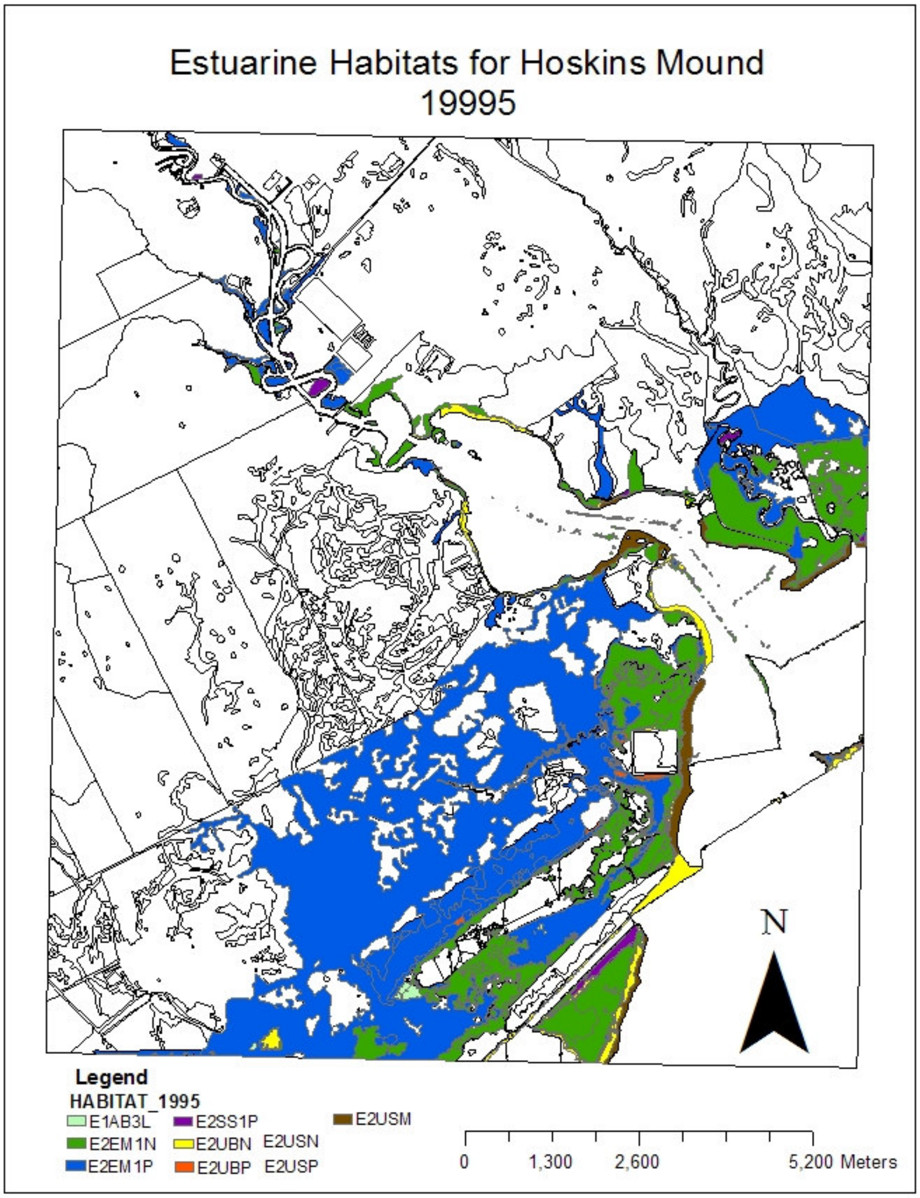
A-11: Highlands quad map



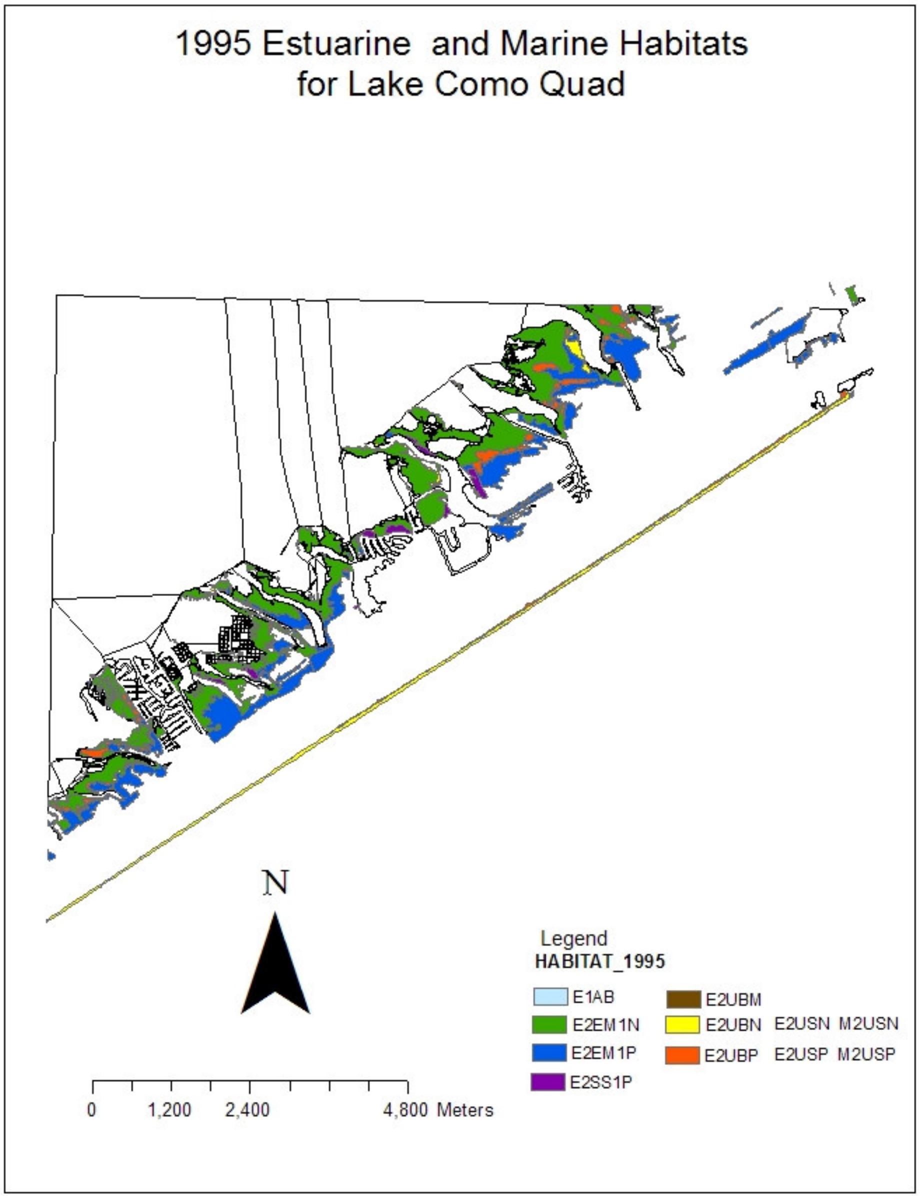
A-12: Hitchcock quad map



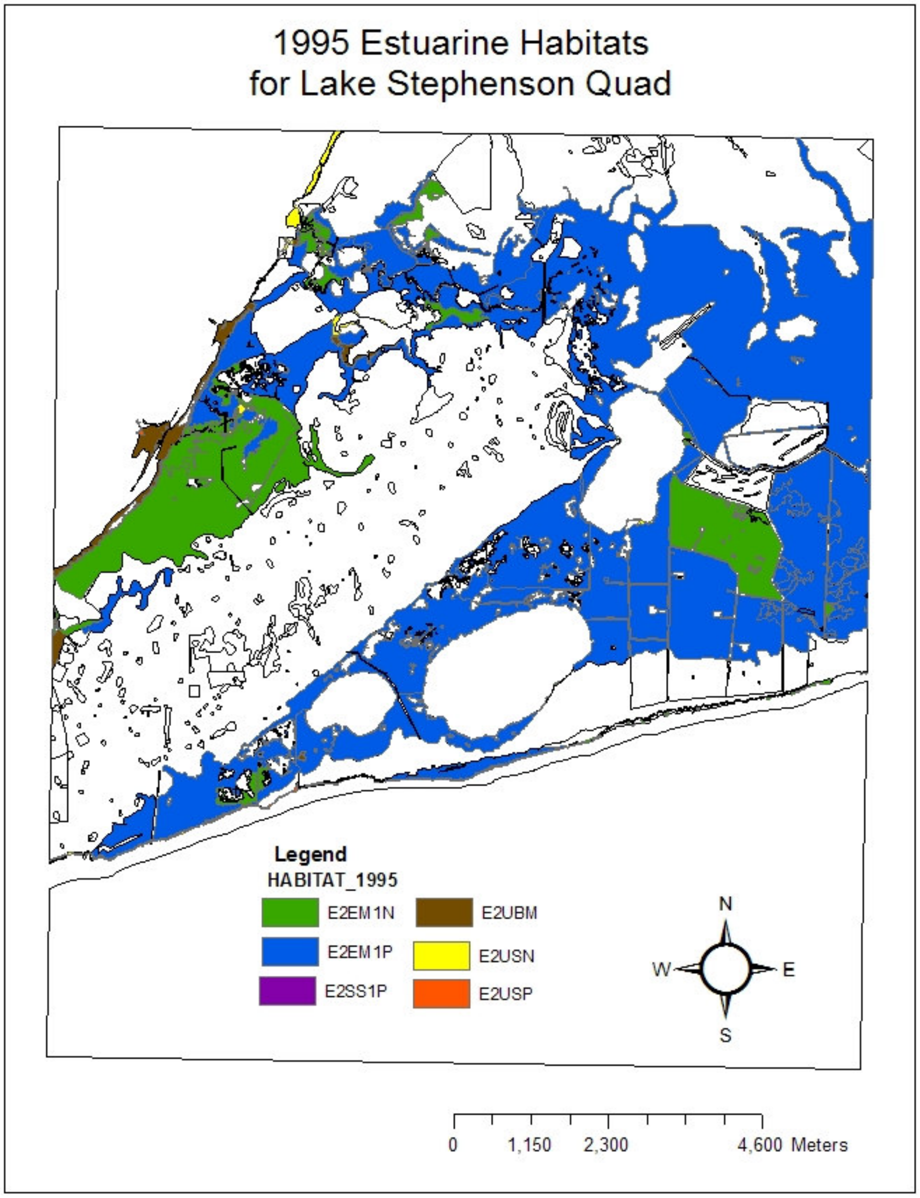
A-13: Hoskins Mound quad map



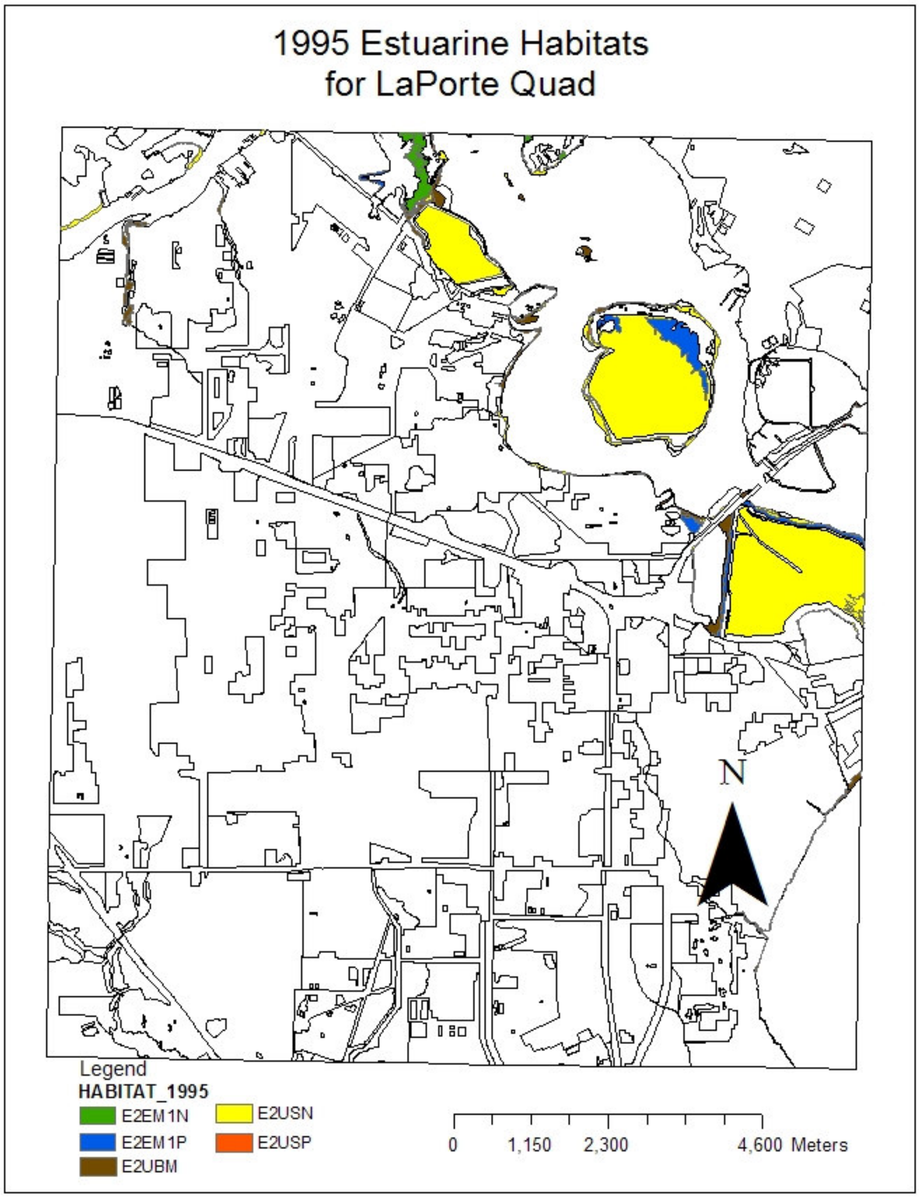
A-14: Lake Como quad map



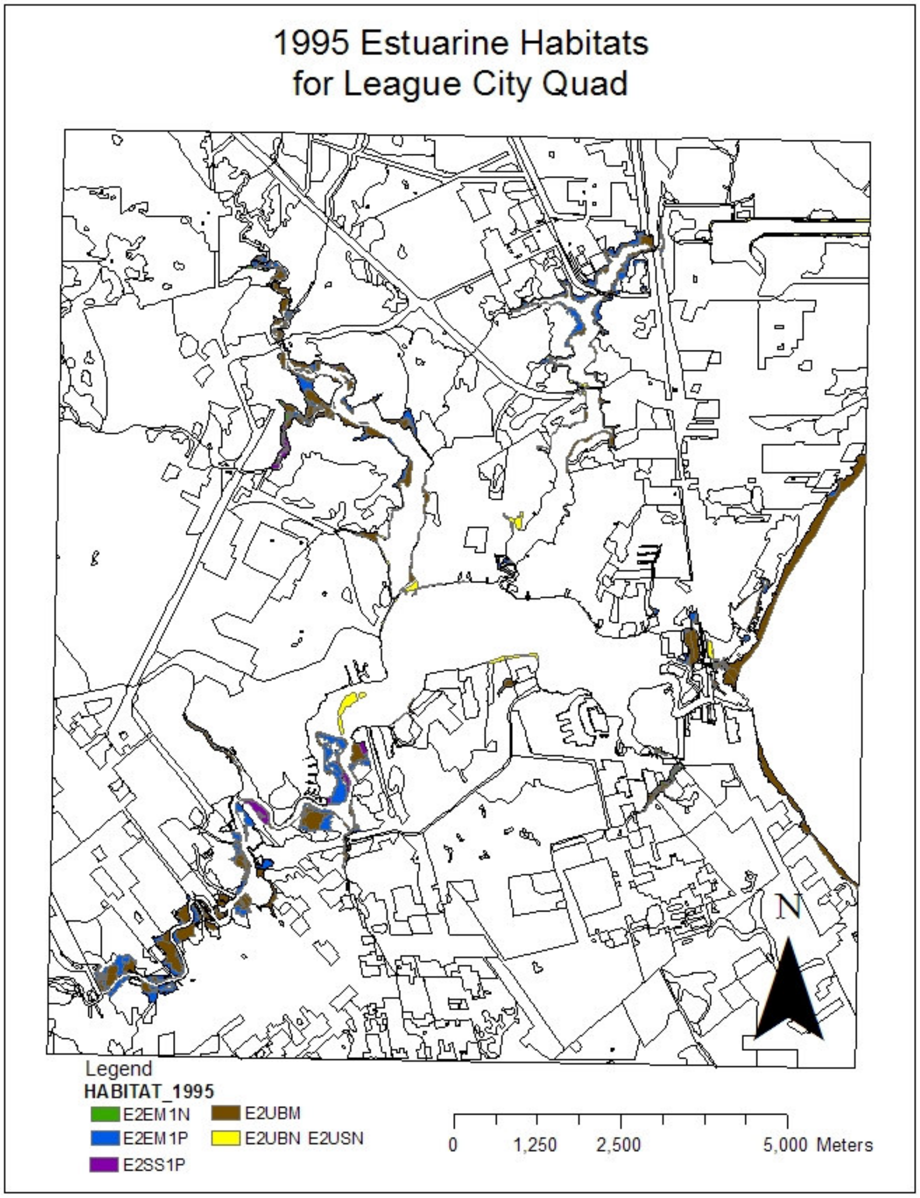
A-15: Lake Stephenson quad map



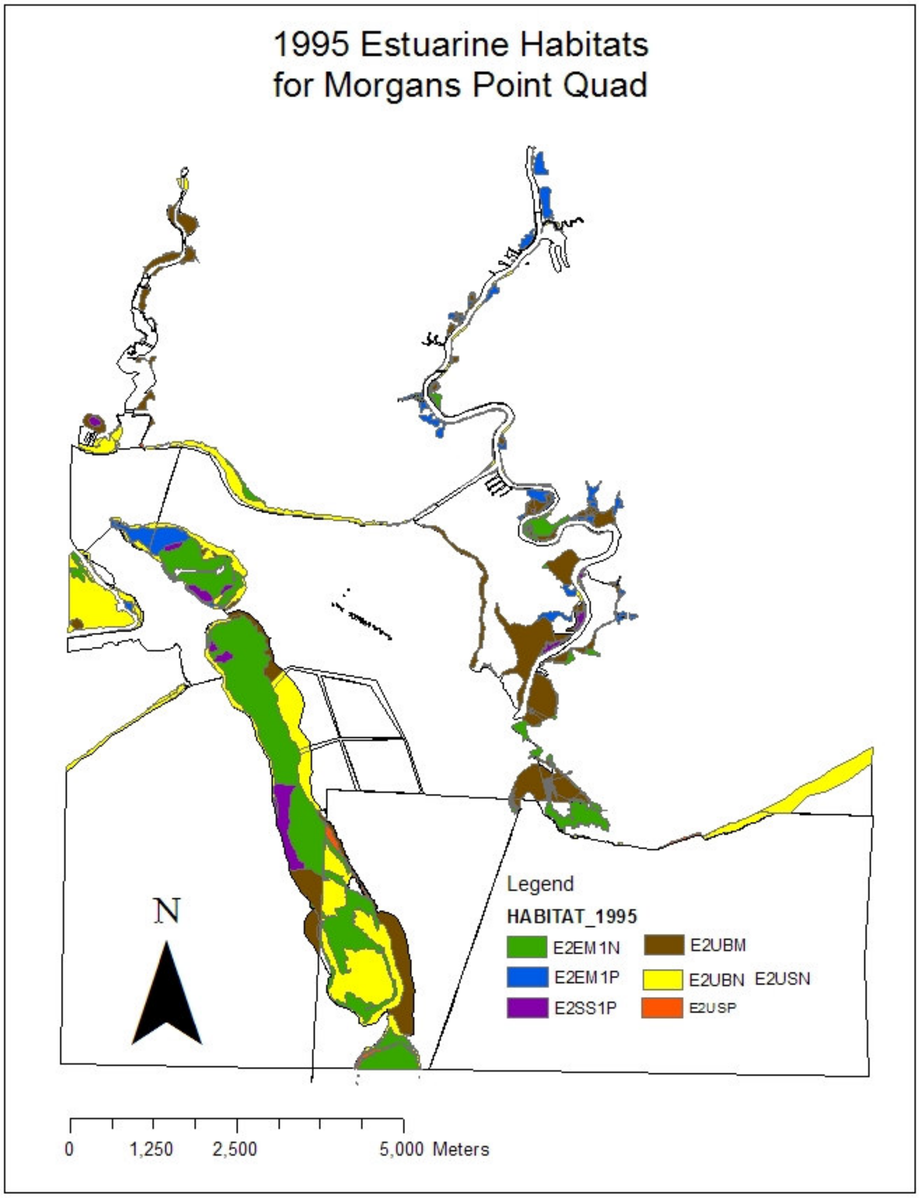
A-16 LaPorte quad map



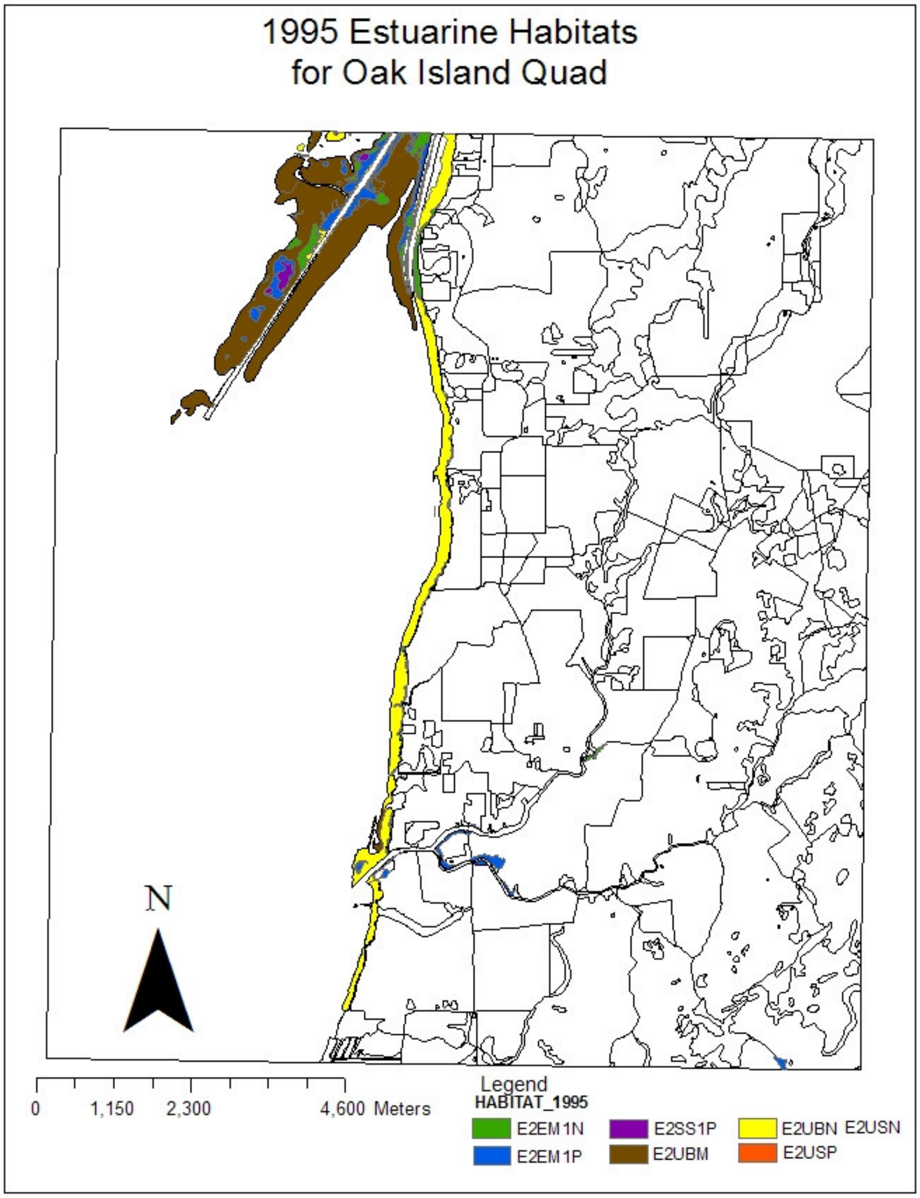
A-17: League City quad map



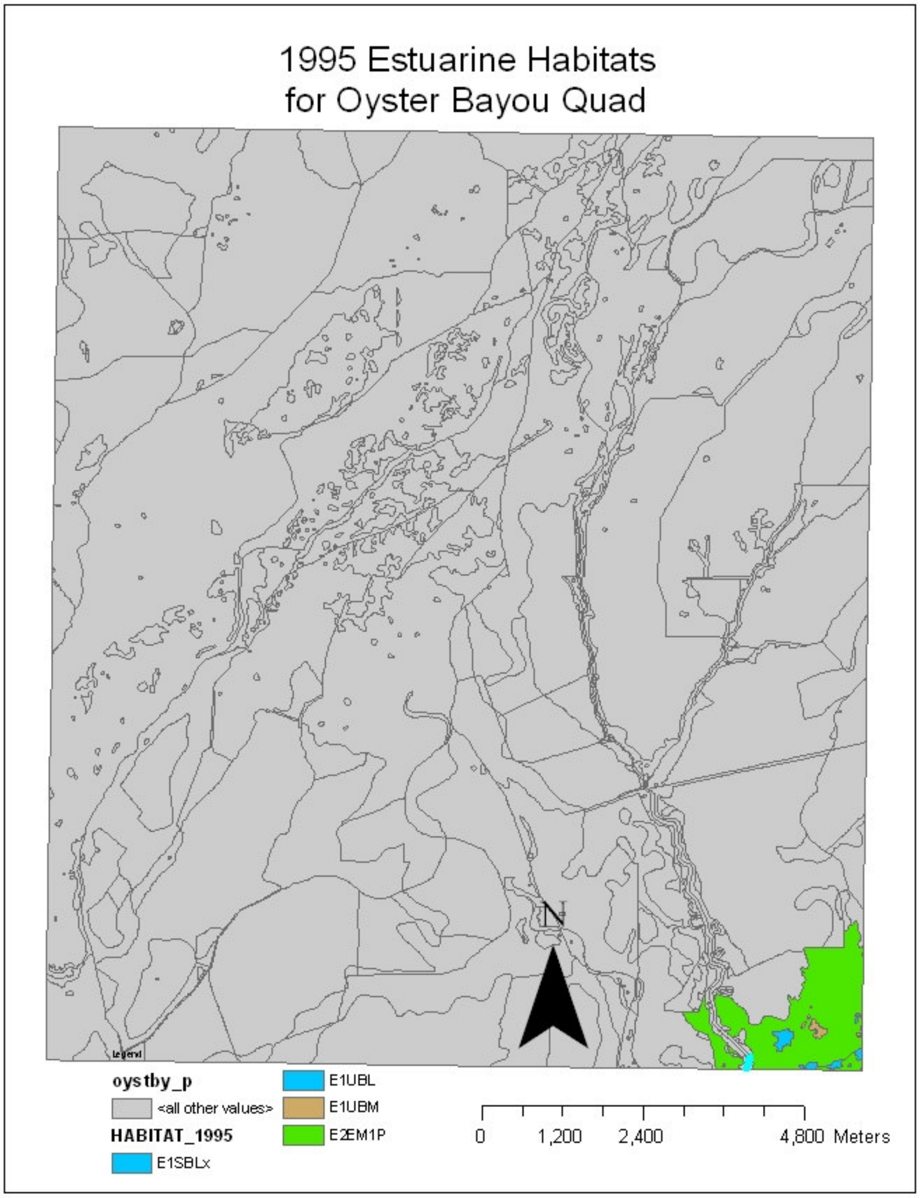
A-18: Morgans Point quad map



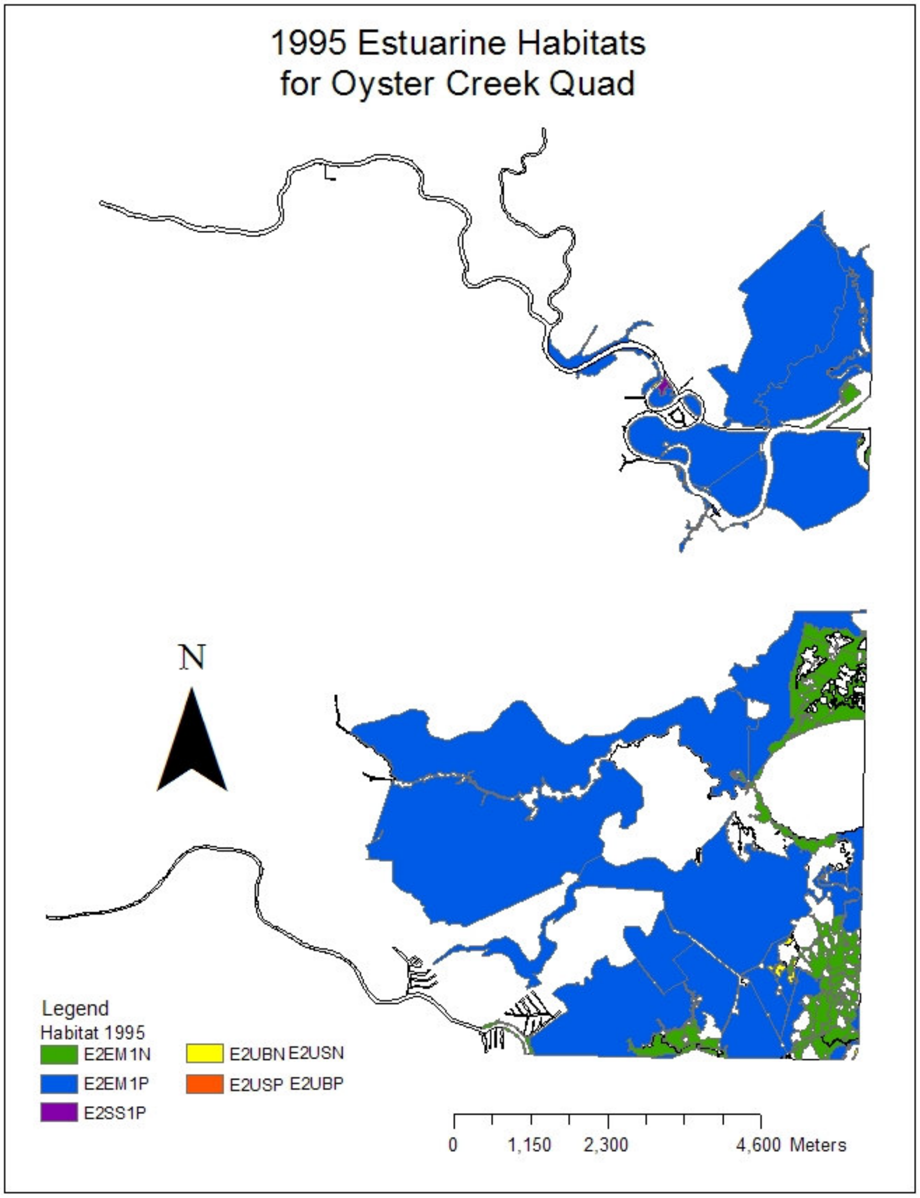
A-19: Oak Island quad map



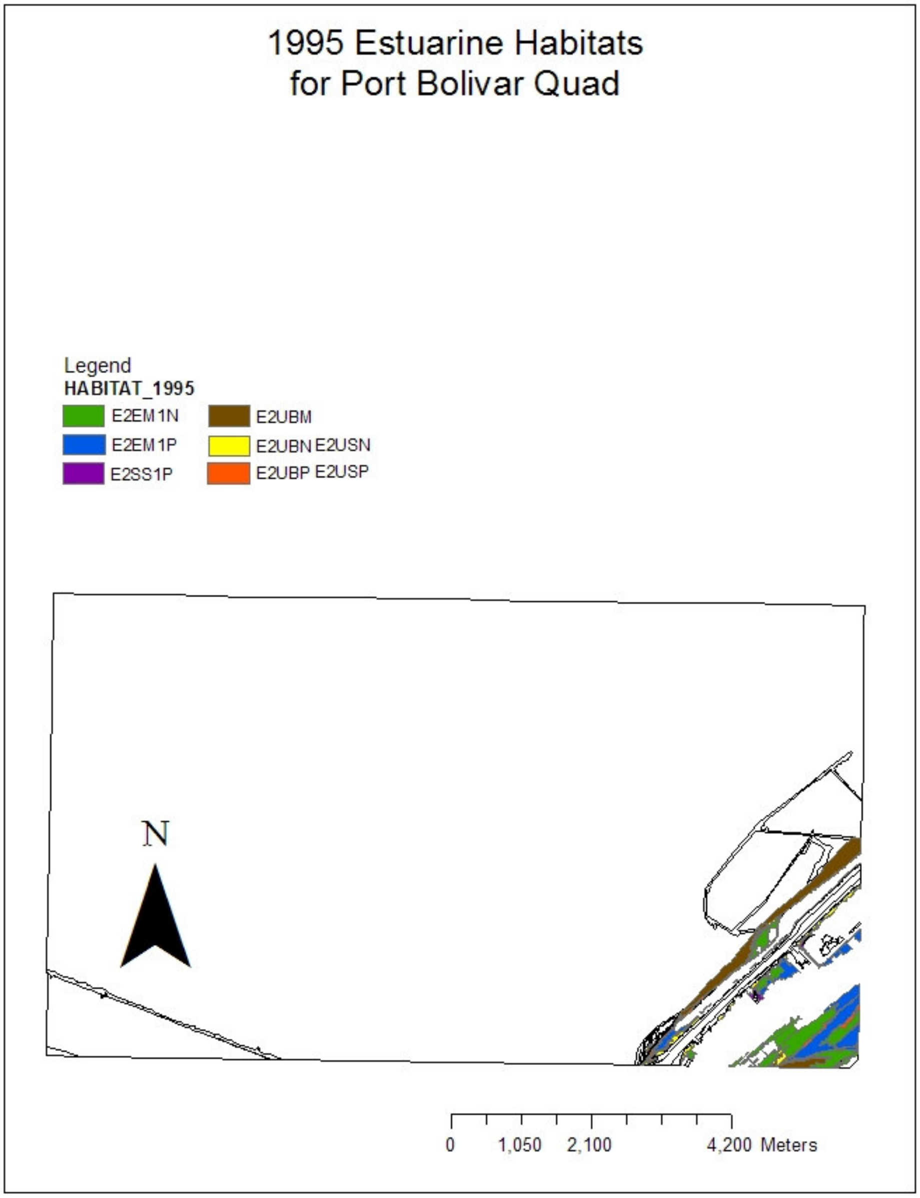
A-20: Oyster Bayou quad map



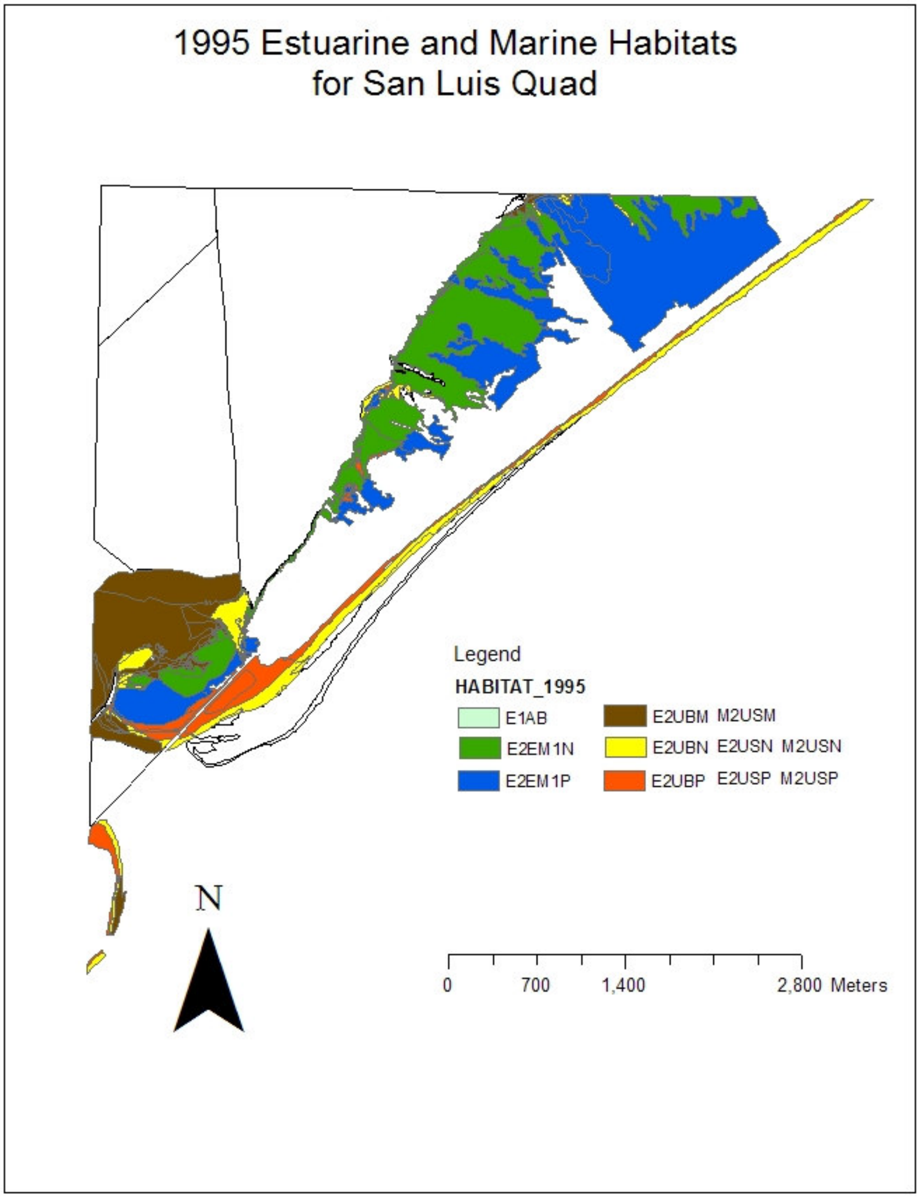
A-21: Oyster Creek quad map



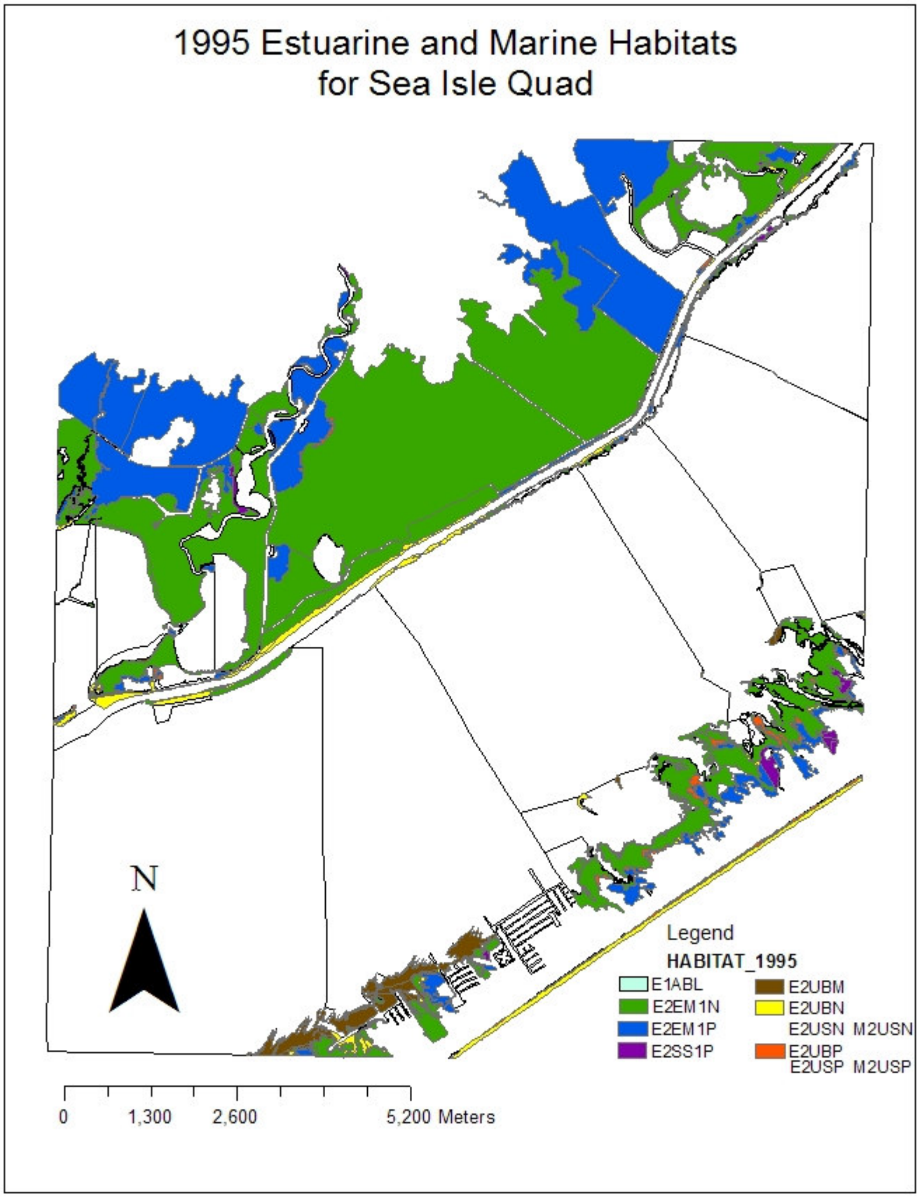
A-22: Port Bolivar quad map



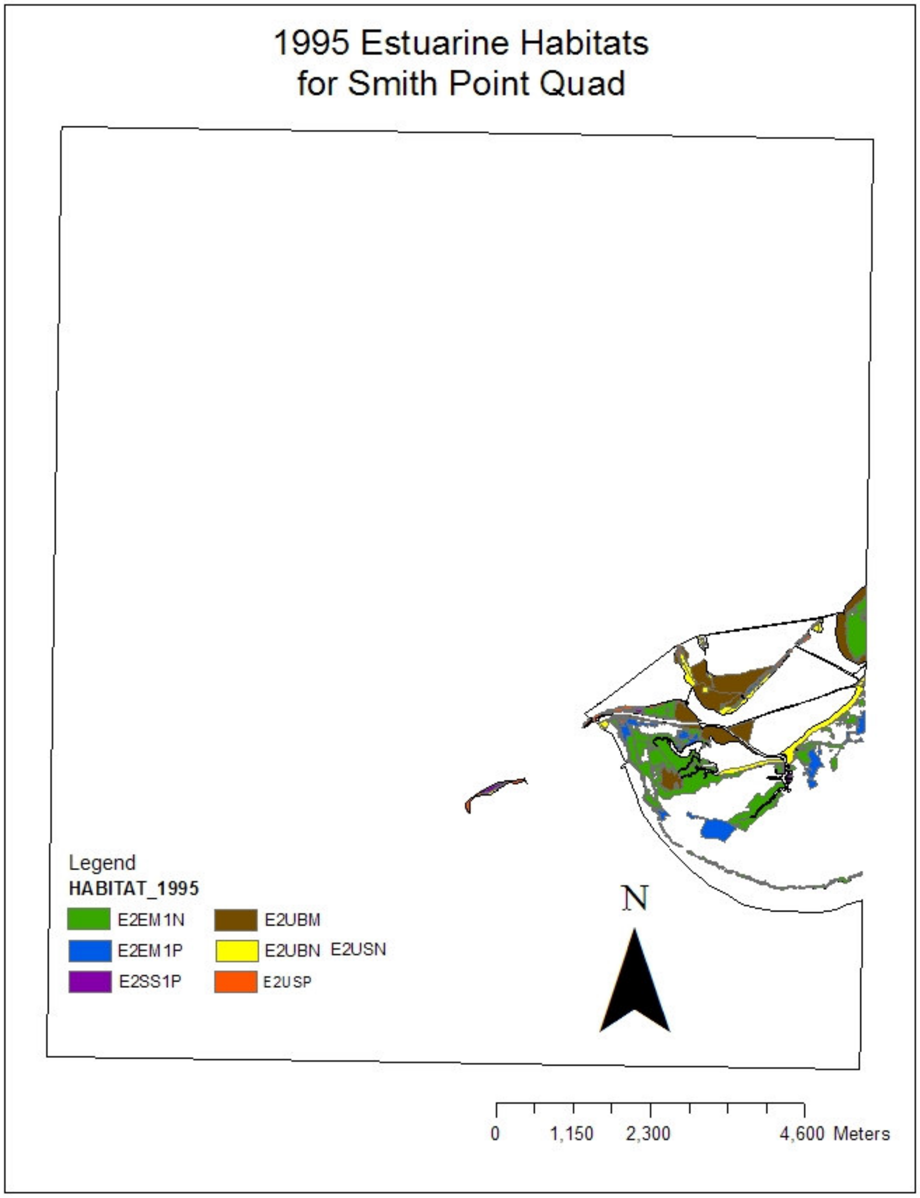
A-23: San Luis quad map



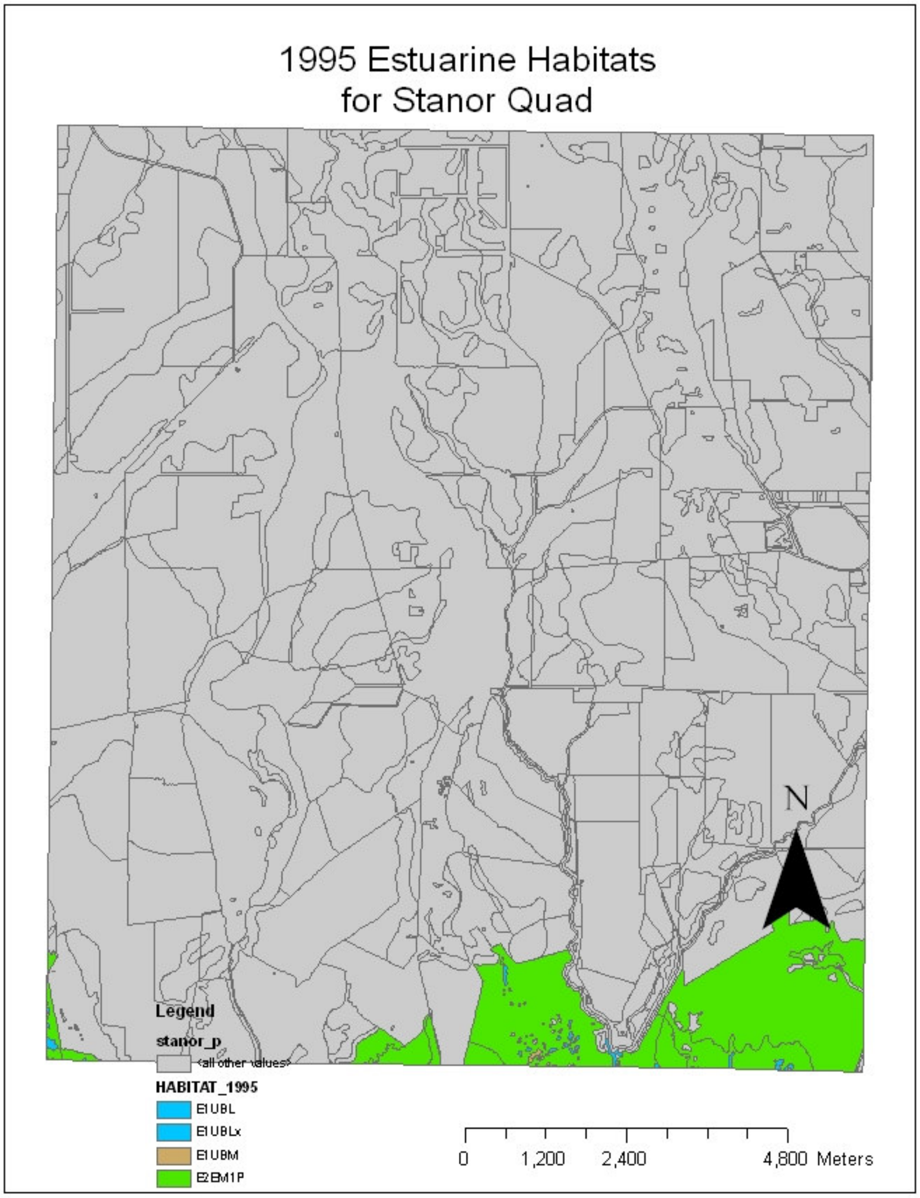
A-24: Sea Isle quad map



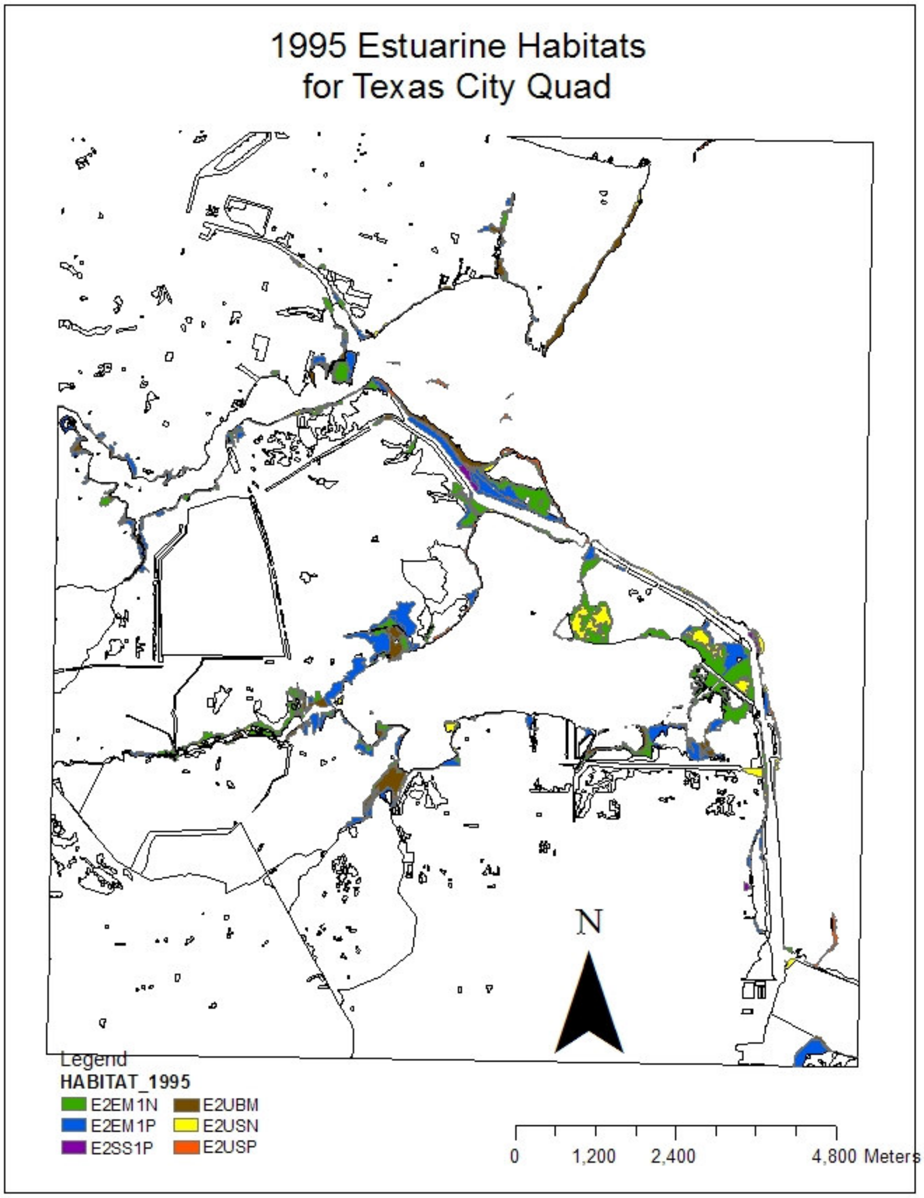
A-25: Smith Point quad map



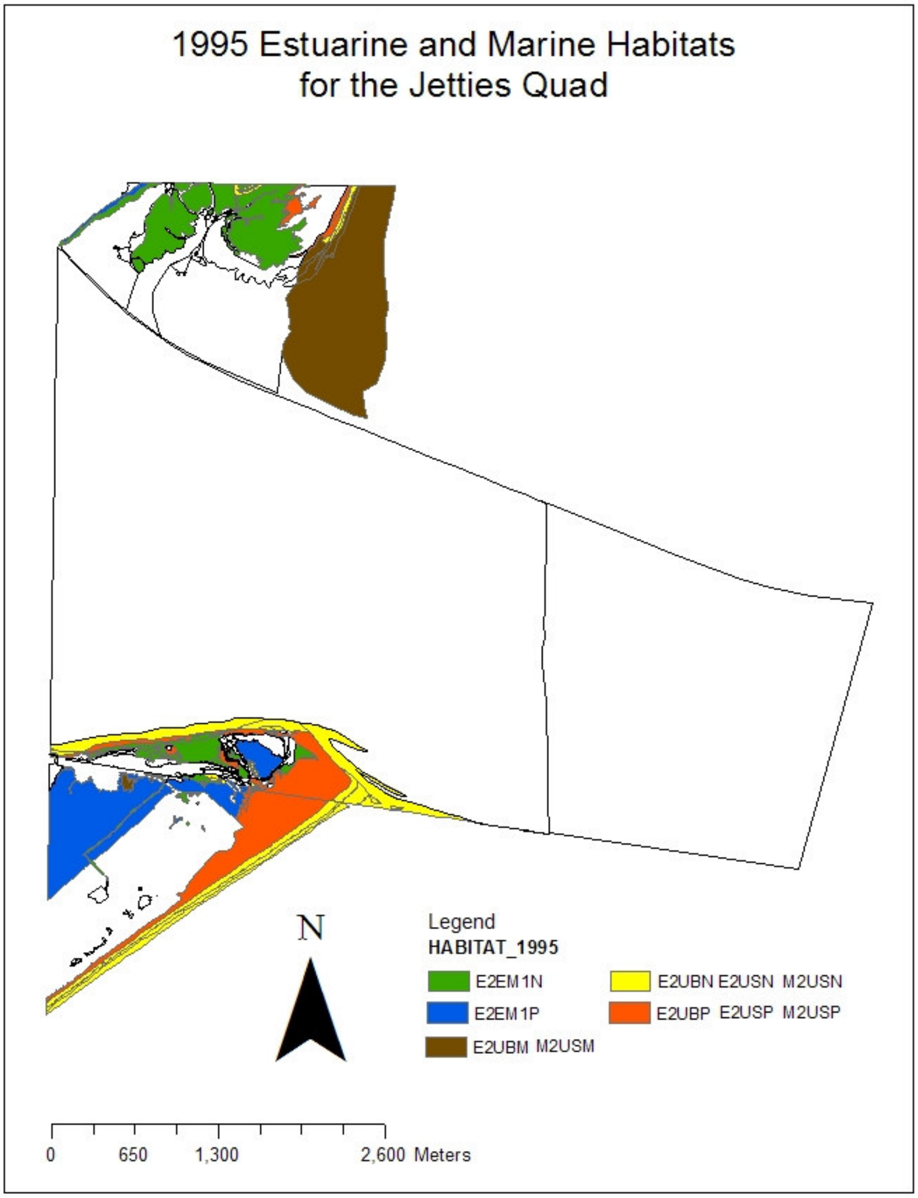
A-26: Stanislind Reservoir quad map



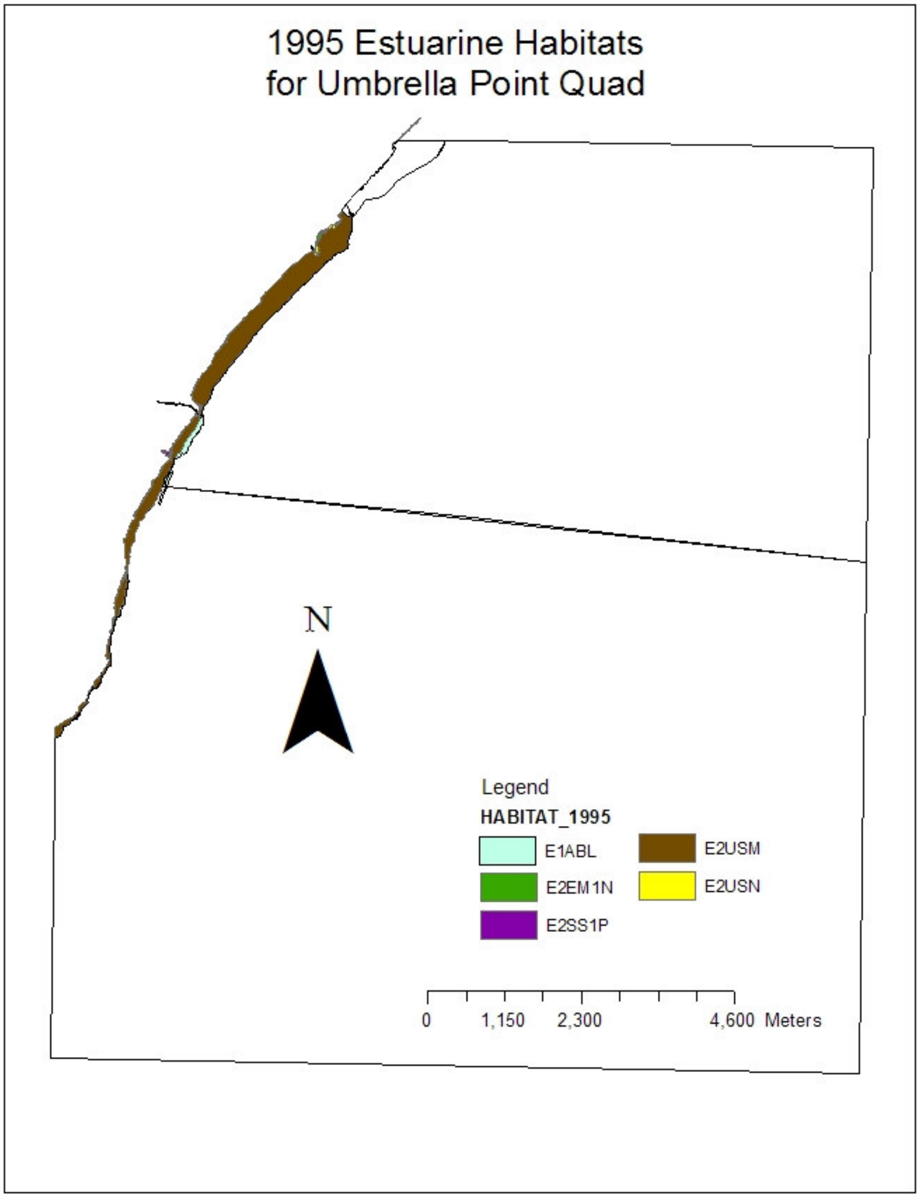
A-27: Texas City quad map



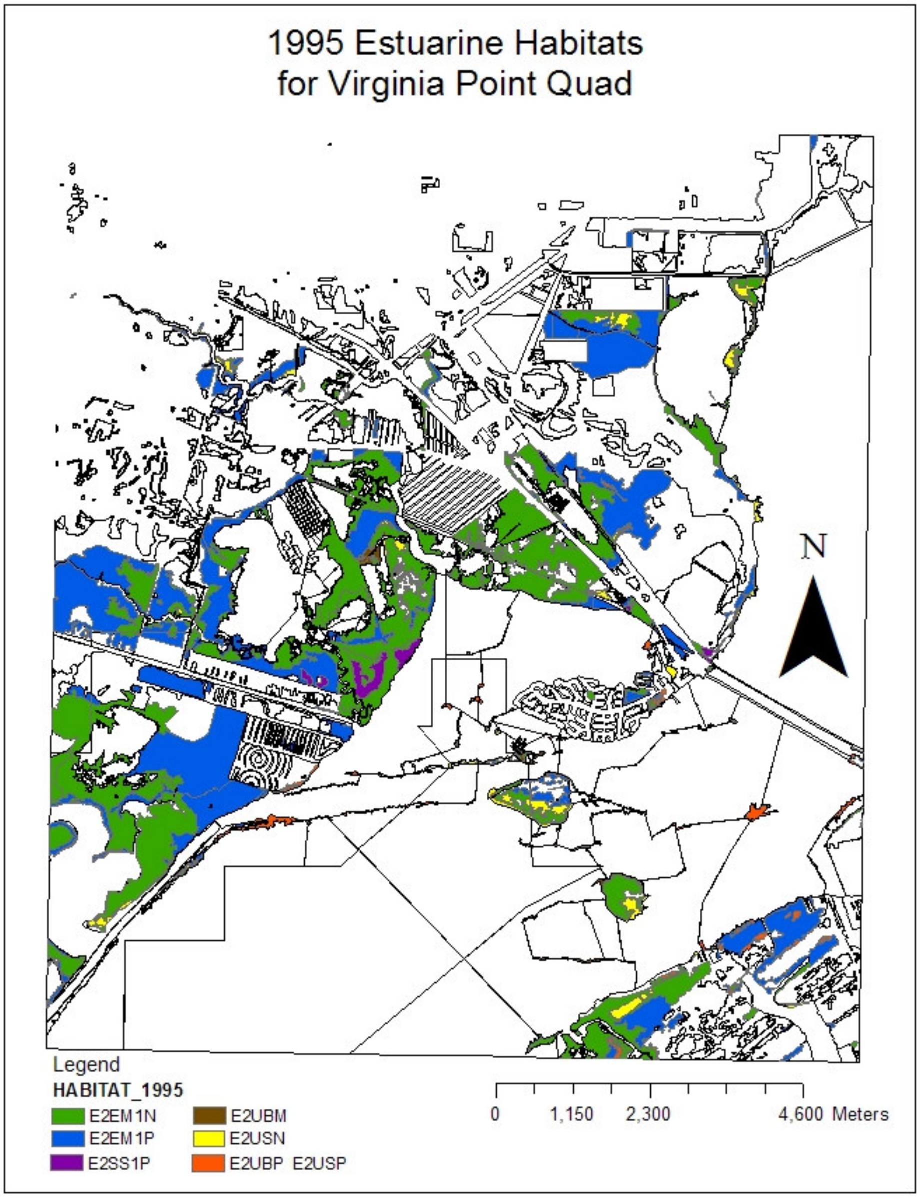
A-28: The Jetties quad map



A-29: Umbrella Point quad map



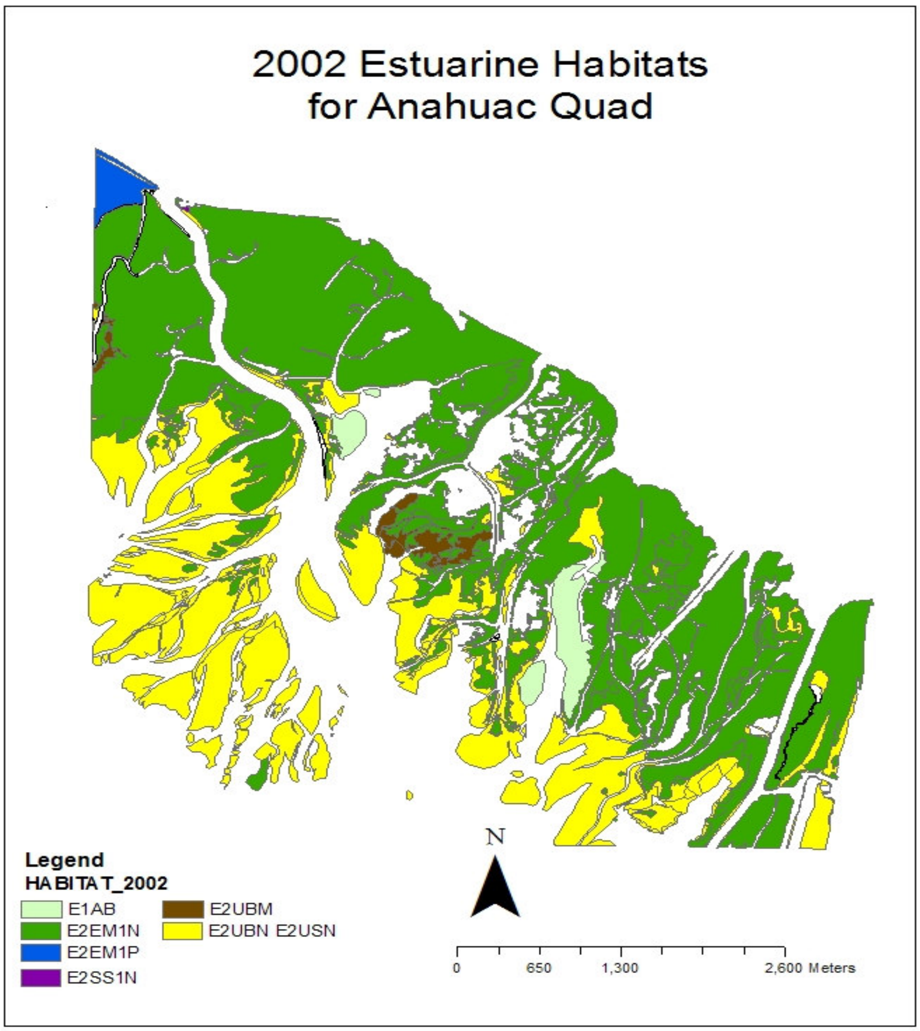
A-30: Virginia Point quad map



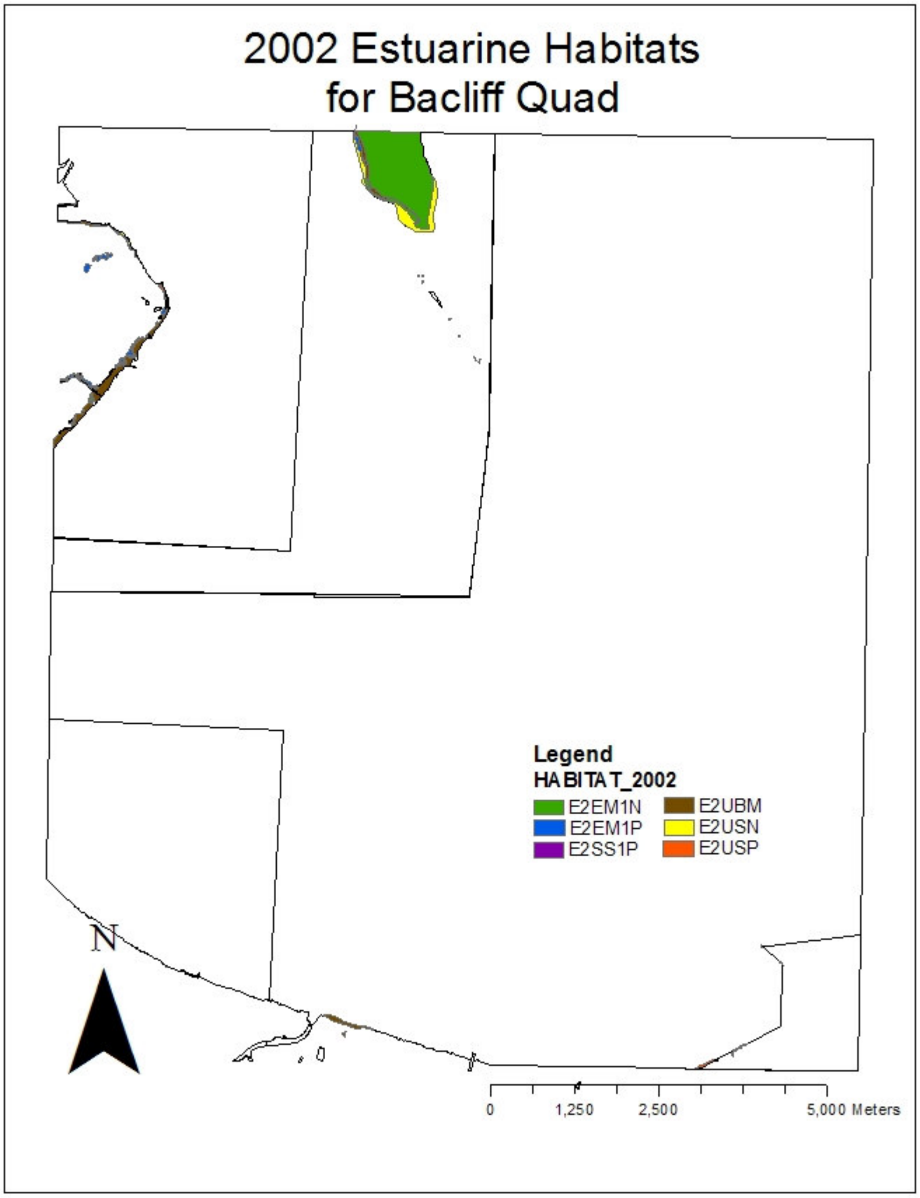
APPENDIX B

MAPS OF MARINE AND ESTUARINE HABITATS FOR INDIVIDUAL QUADS PRESENT IN THE YEAR 2002

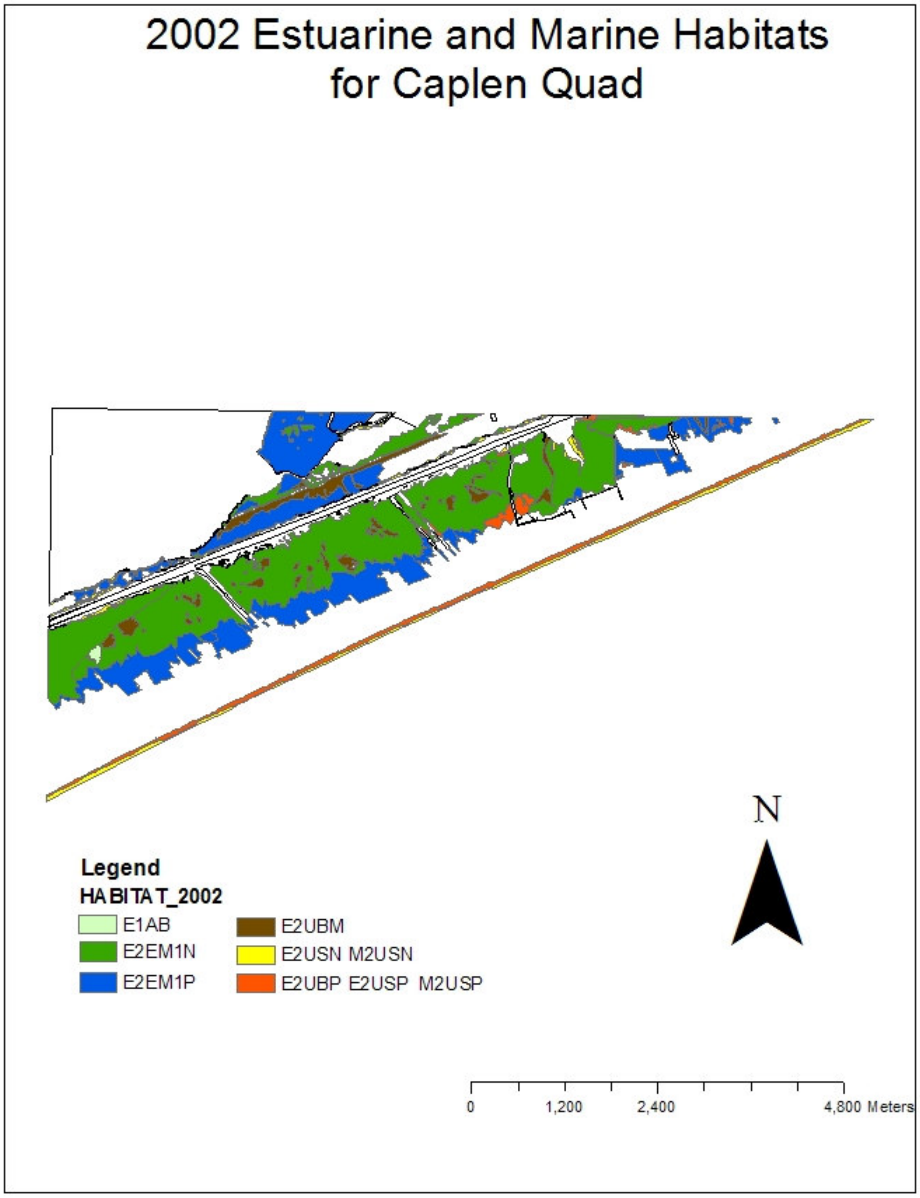
B-1: Anahuac quad map



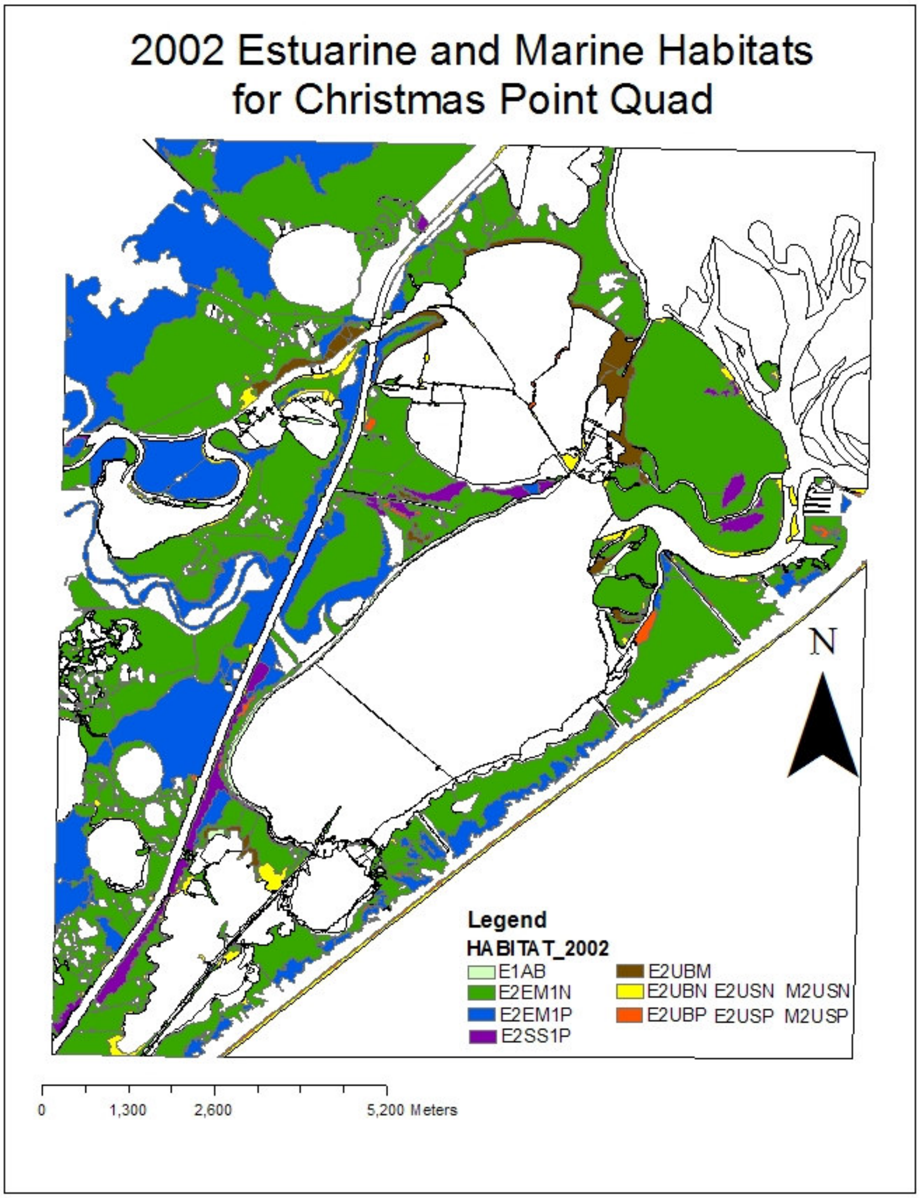
B-2: Bacliff quad map



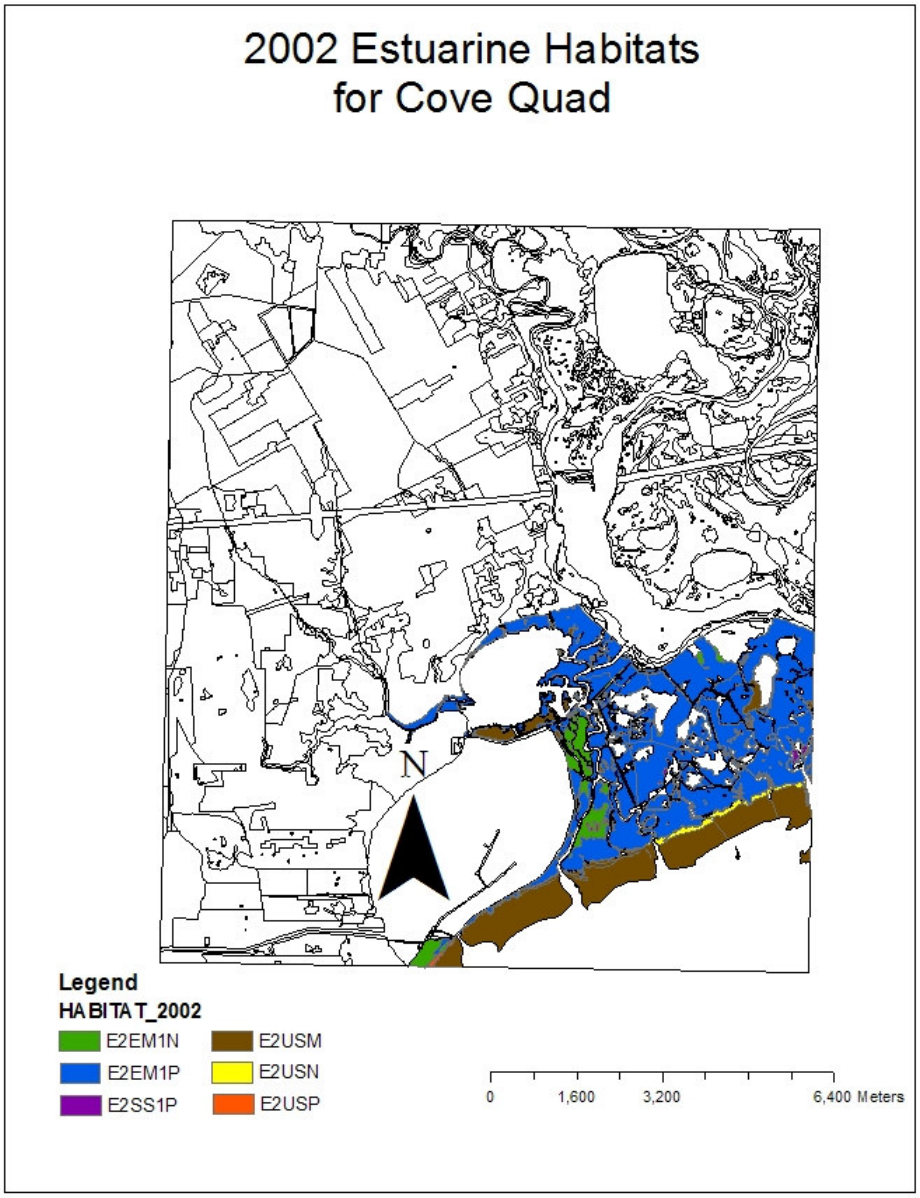
B-3: Caplen quad map



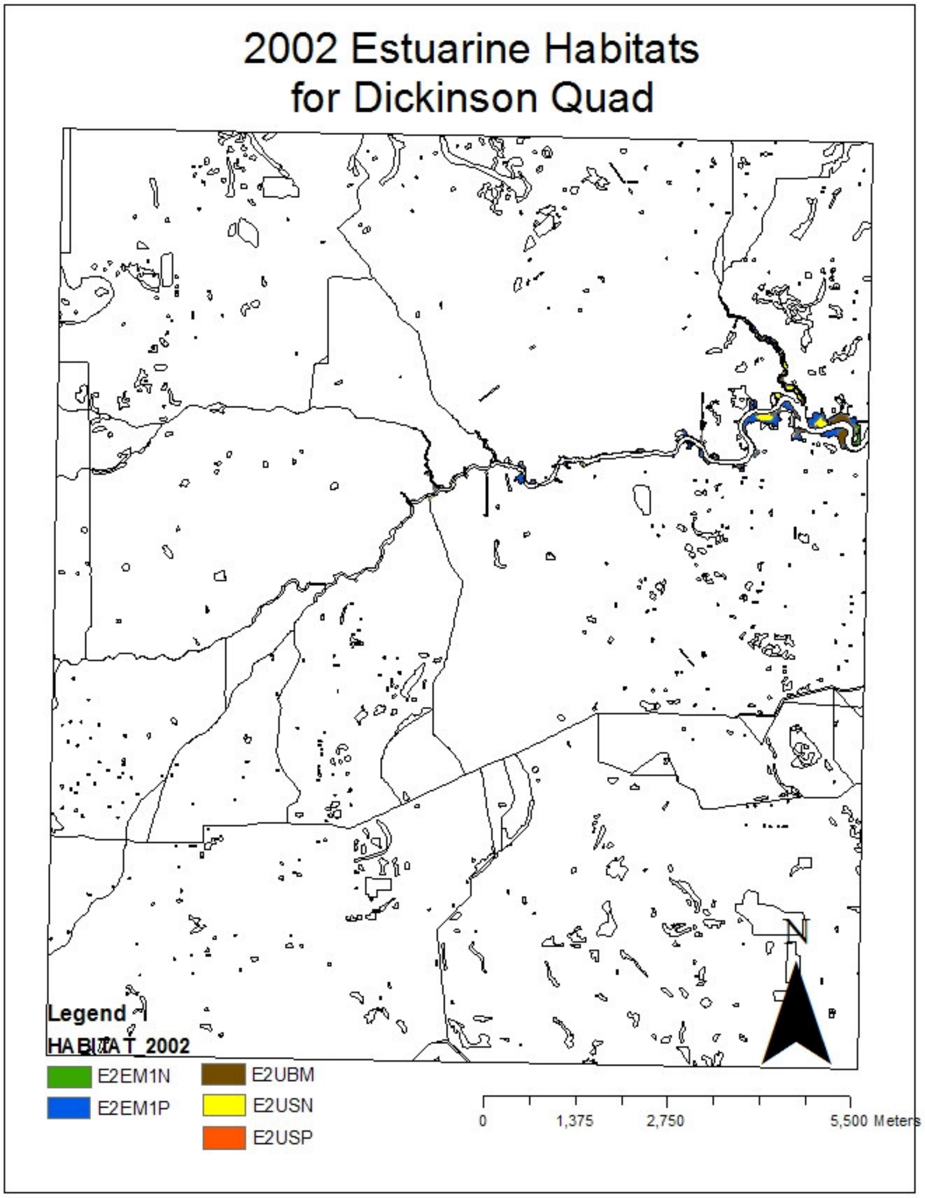
B-4: Christmas Point quad map



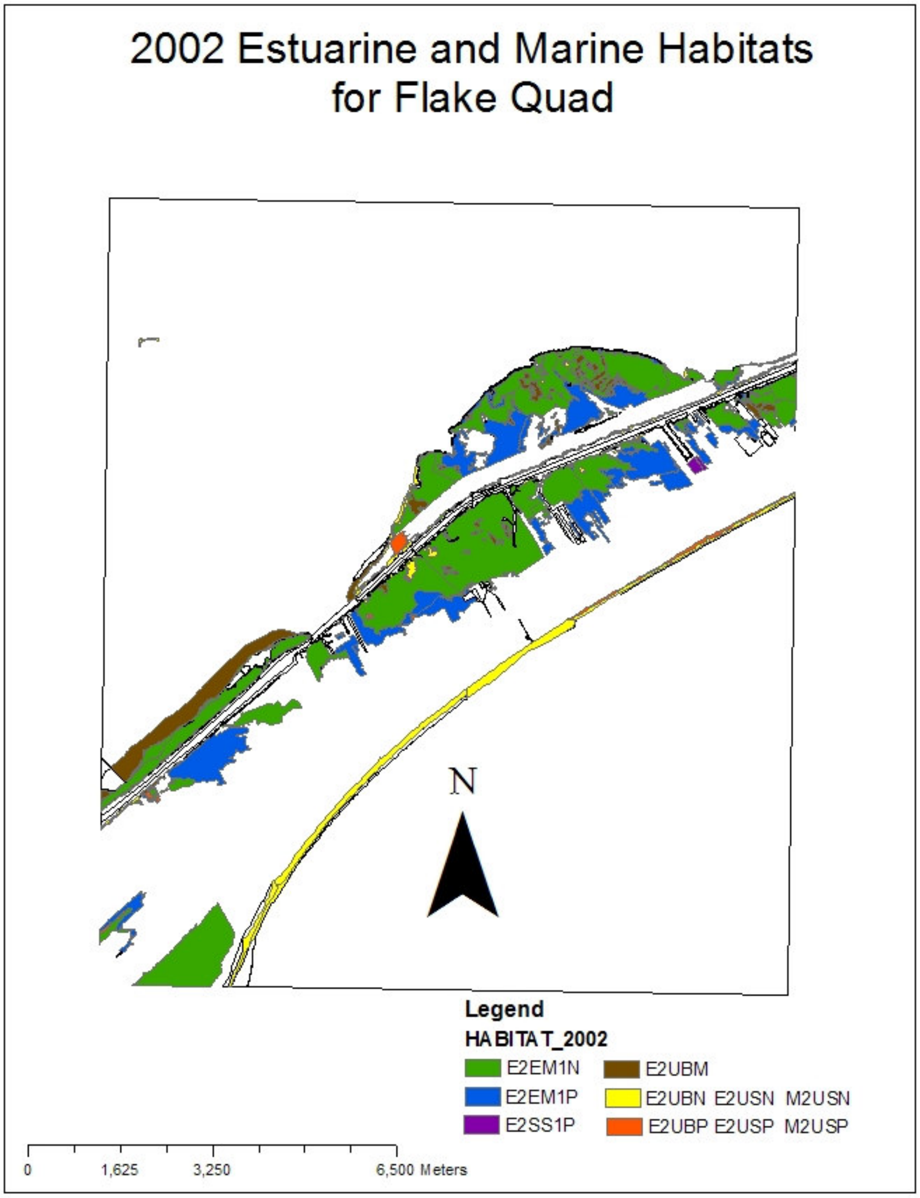
B-5: Cove quad map



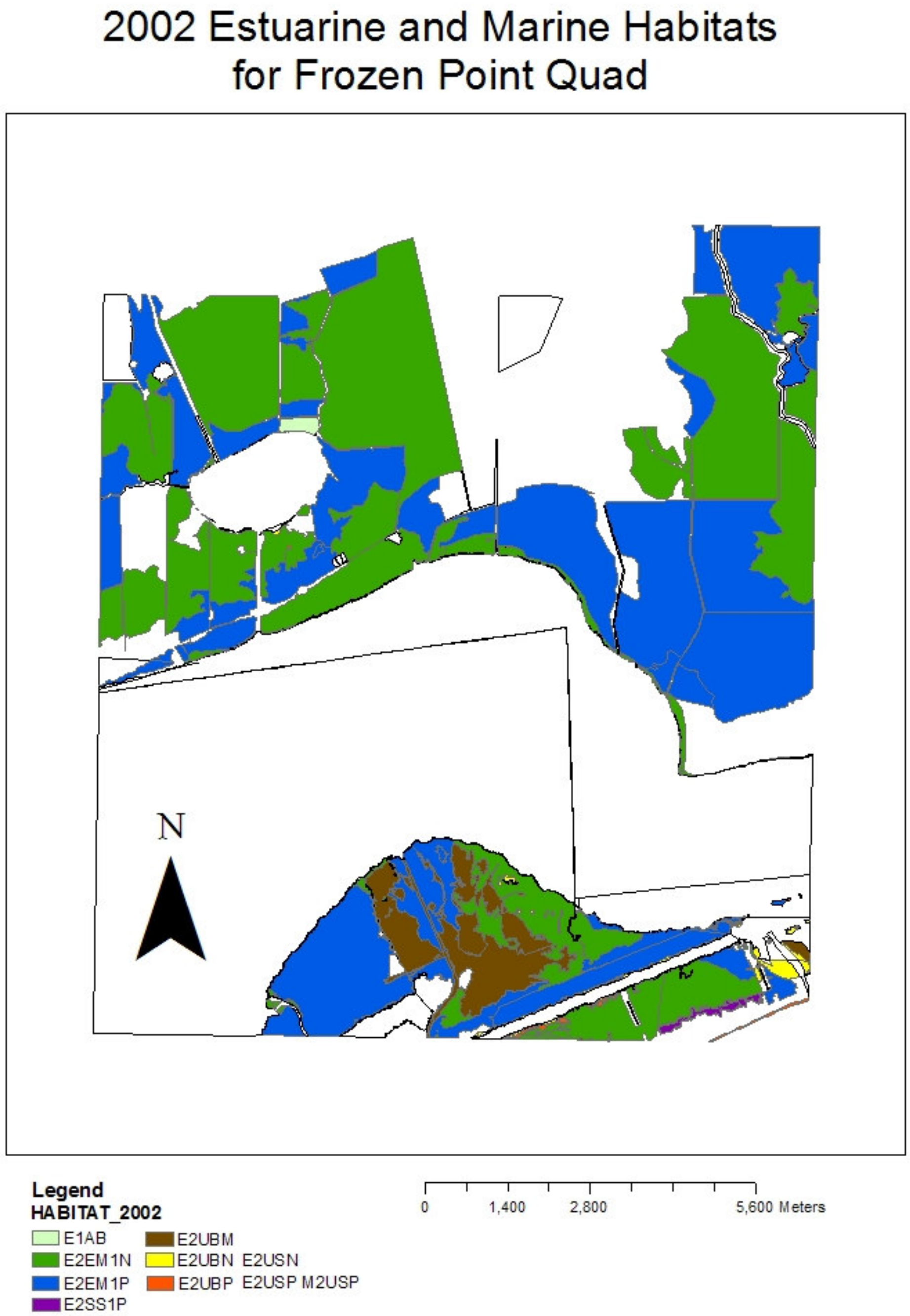
B-6: Dickinson quad map



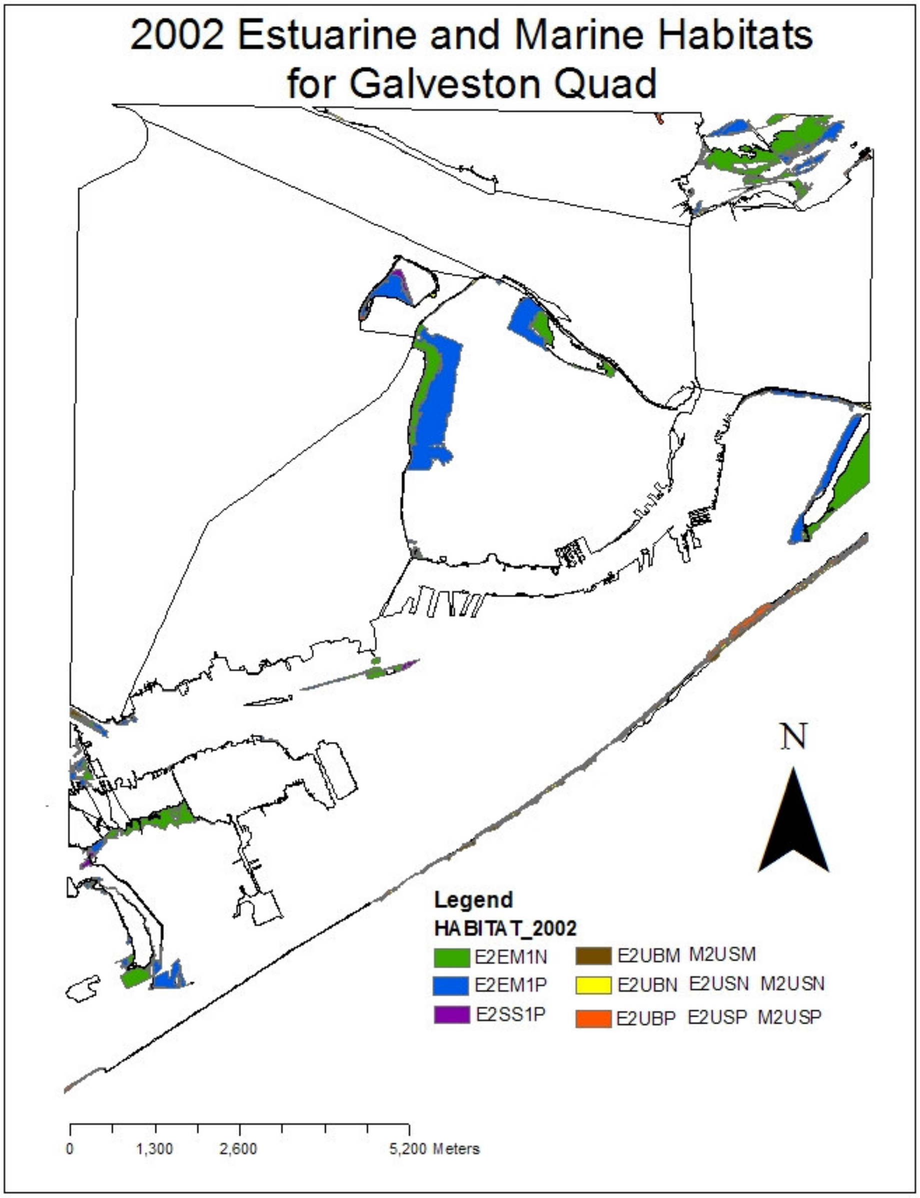
B-7: Flake quad map



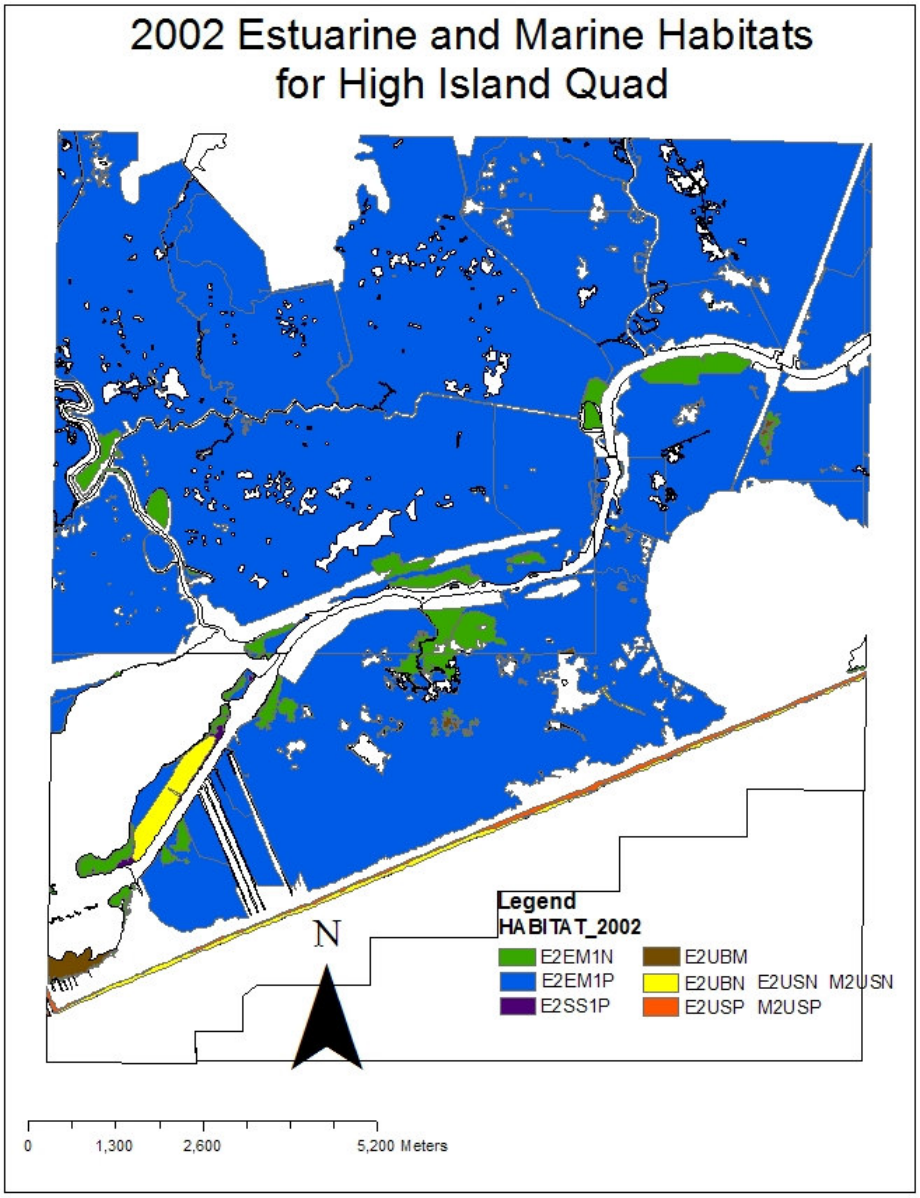
B-8: Frozen Point quad map



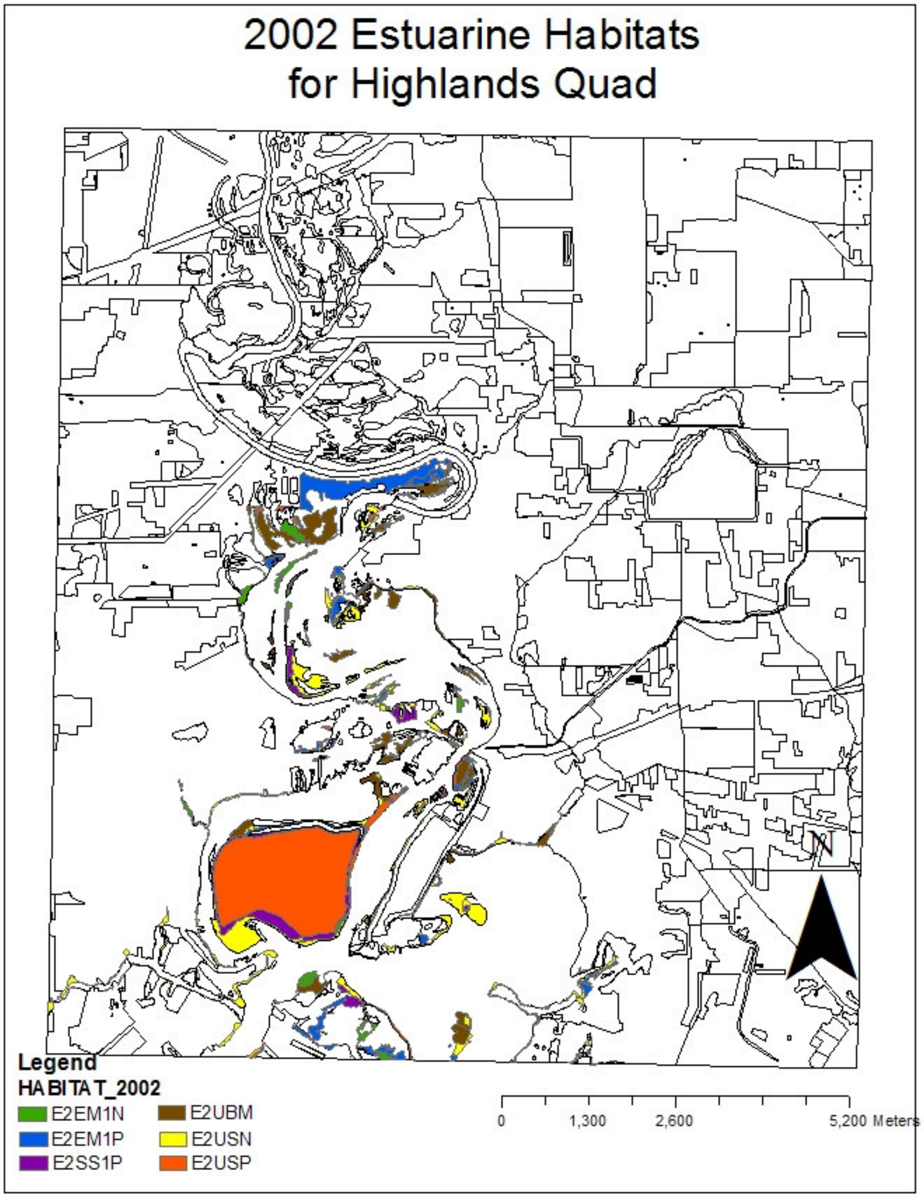
B-9: Galveston quad map



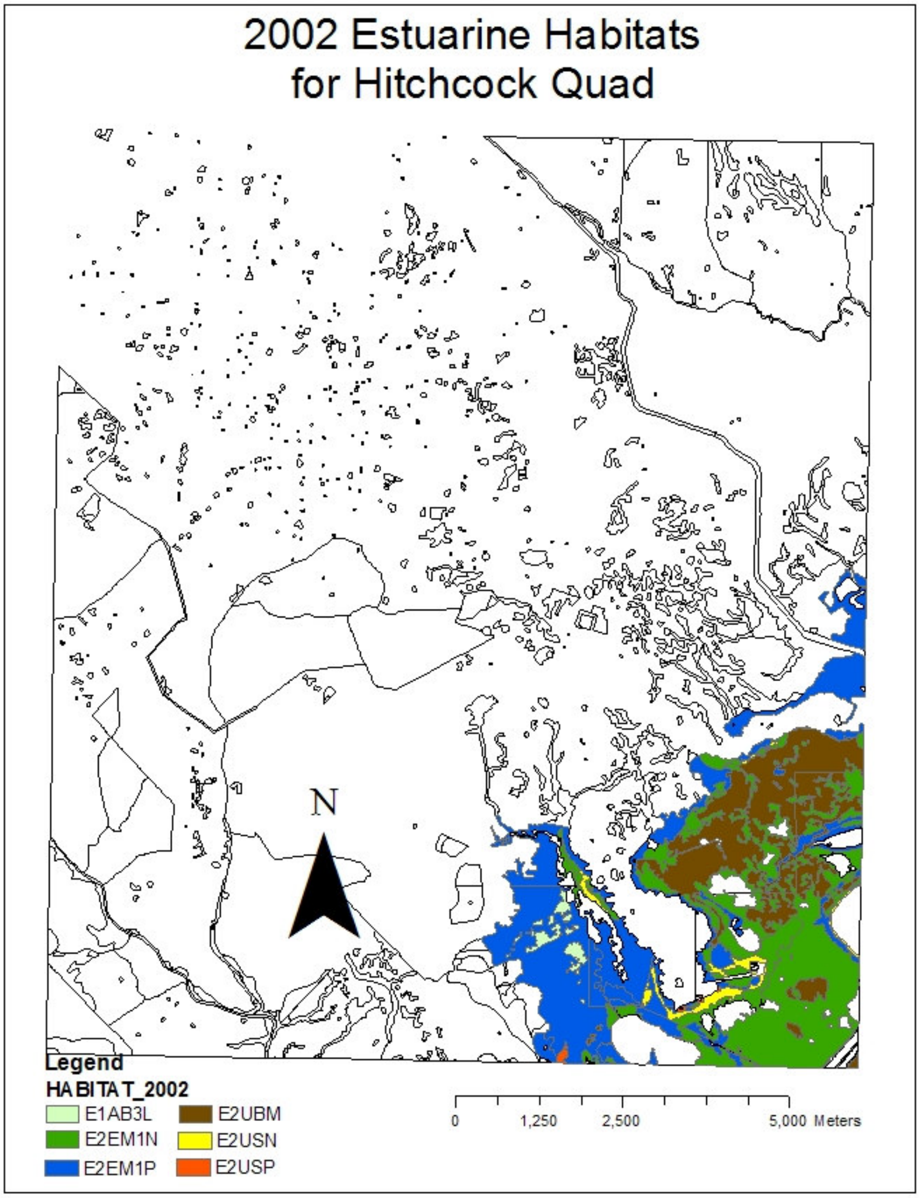
B-10: High Island quad map



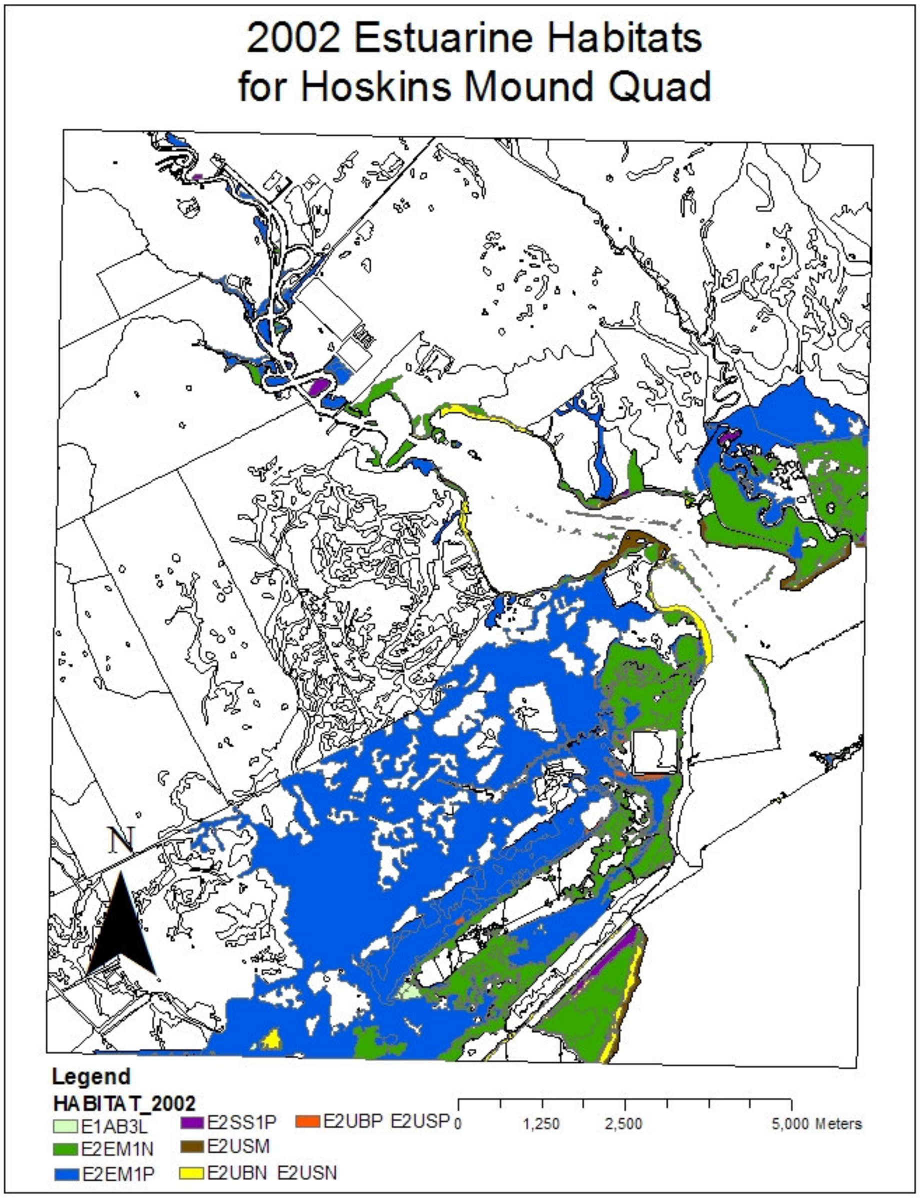
B-11: Highlands quad map



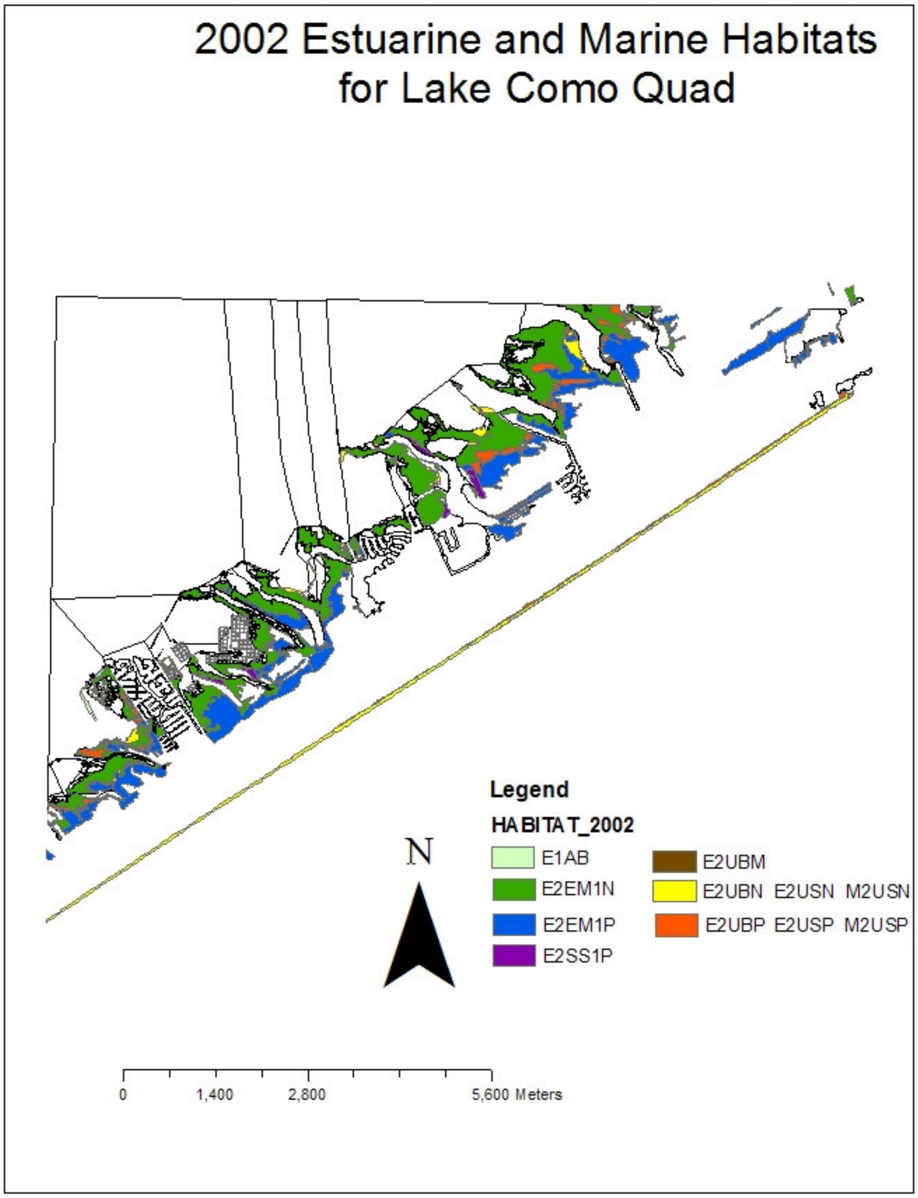
B-12: Hitchcock quad map



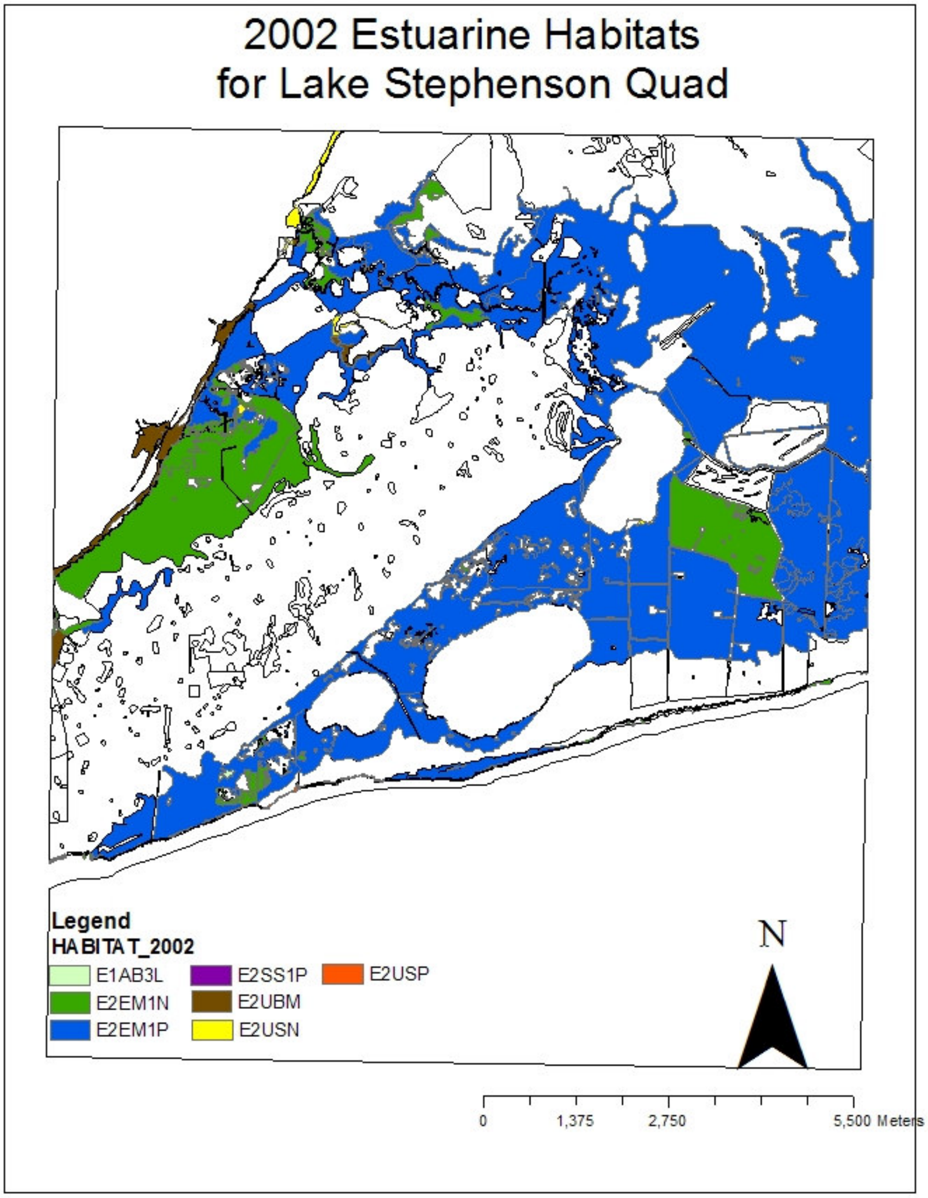
B-13: Hoskins Mound quad map



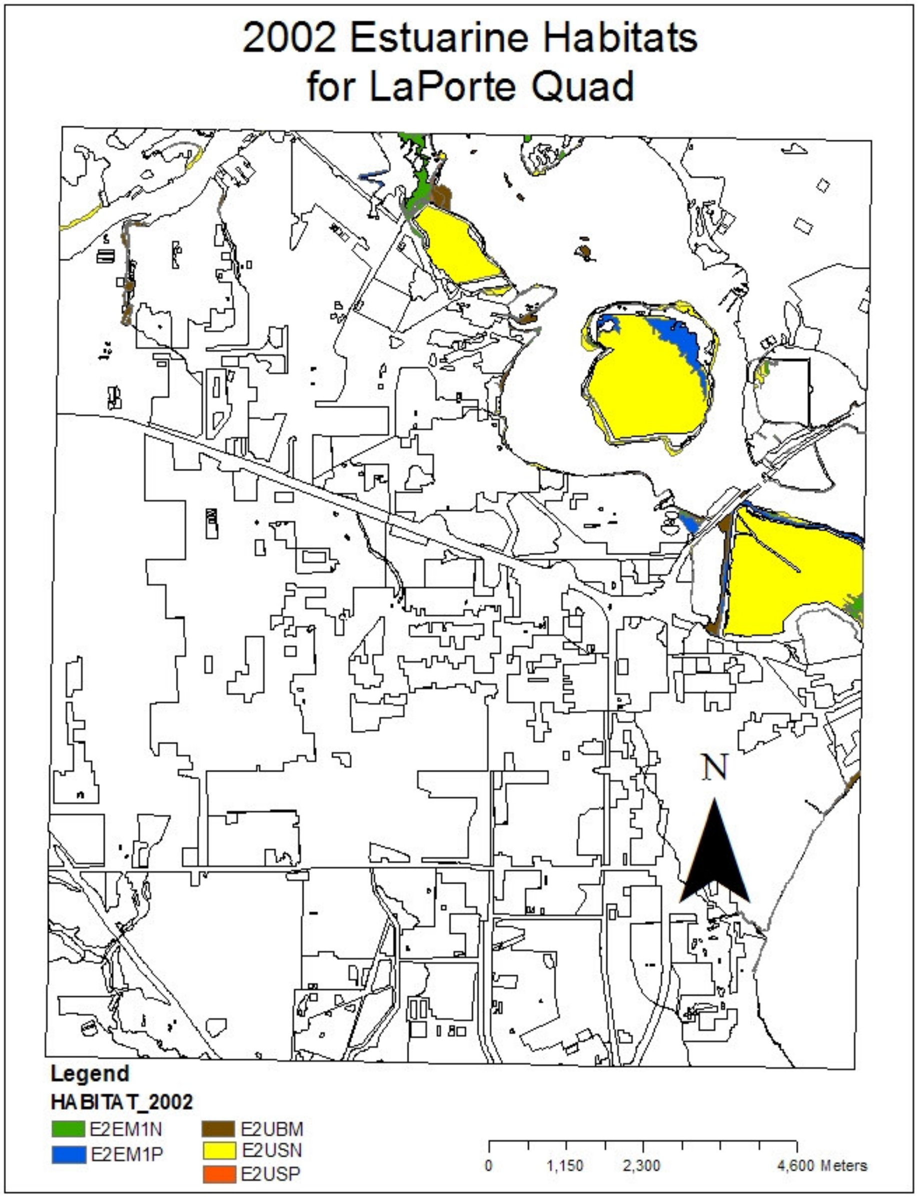
B-14: Lake Como quad map



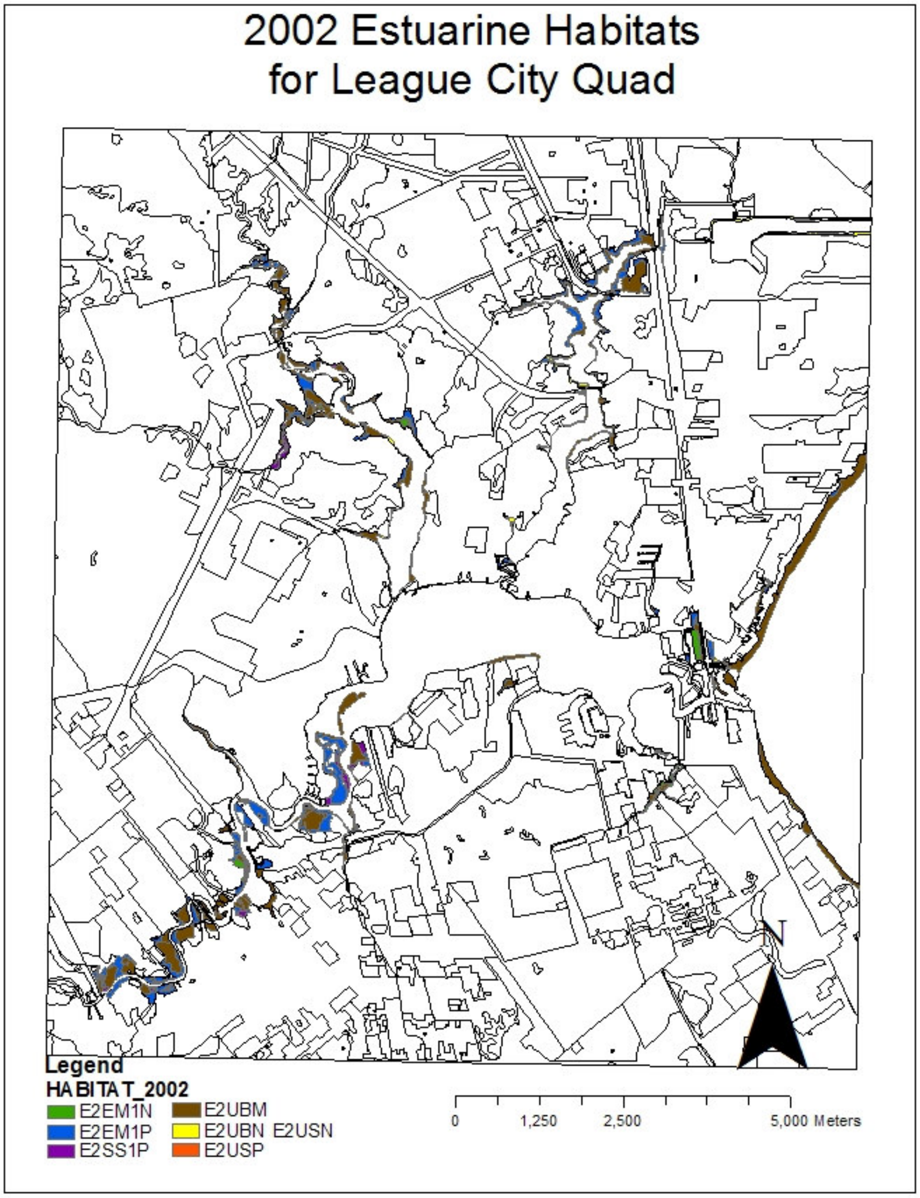
B-15: Lake Stephenson quad map



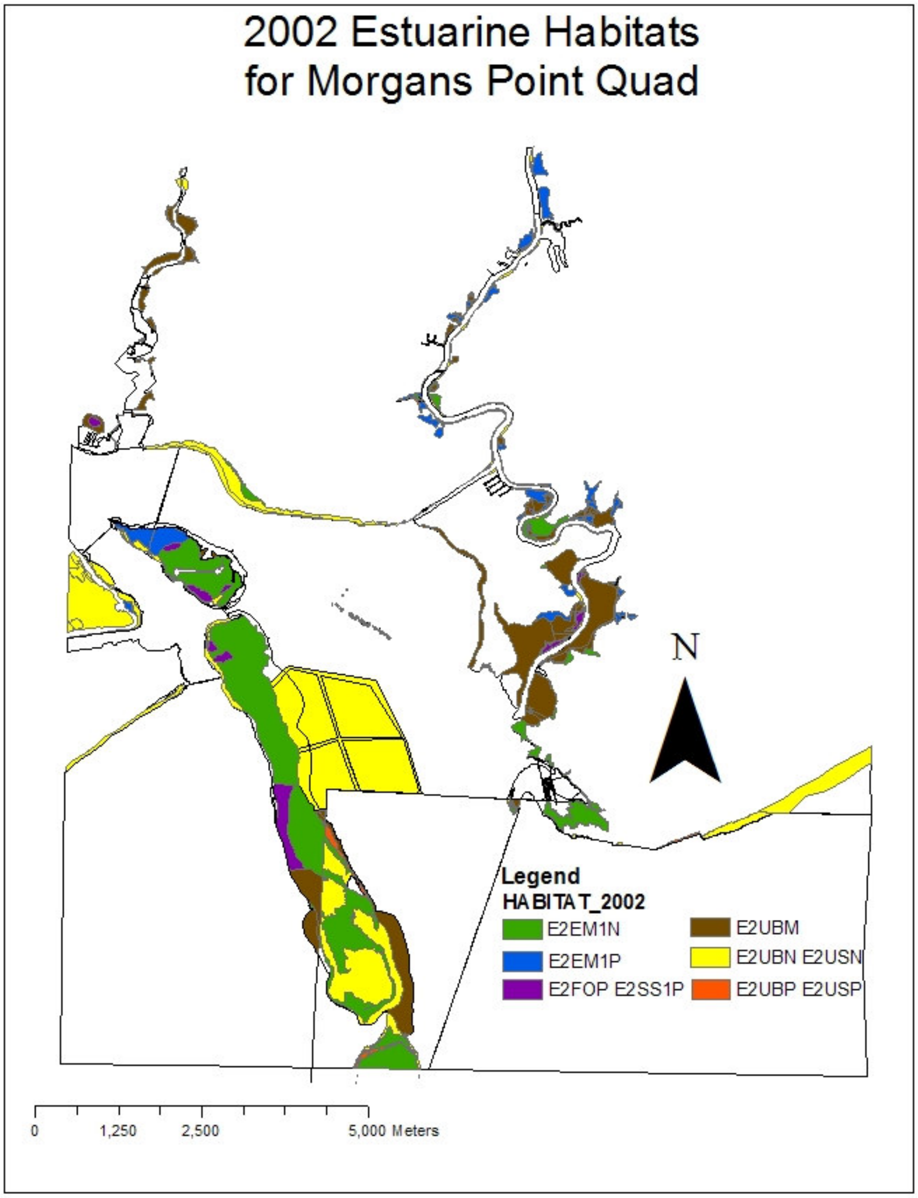
B-16: LaPorte quad map



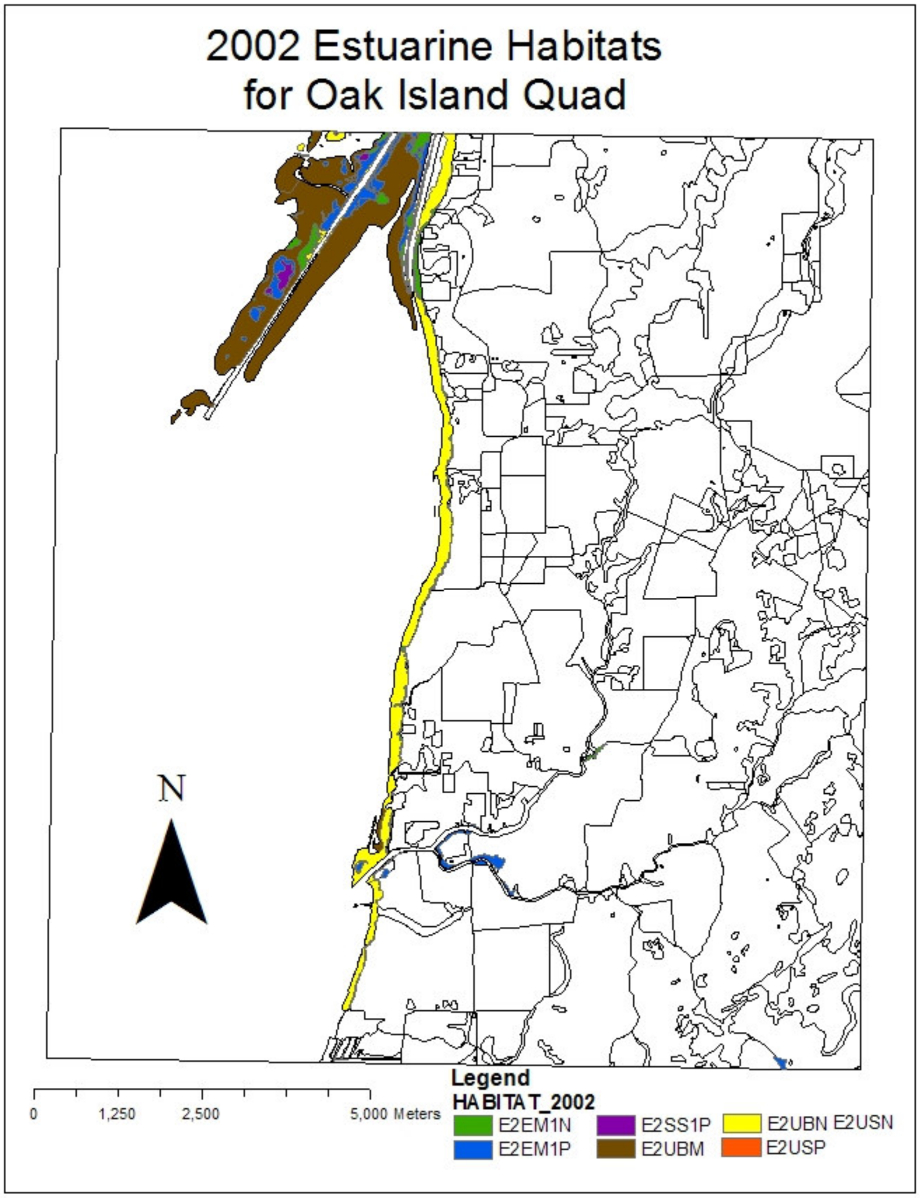
B-17: League City quad map



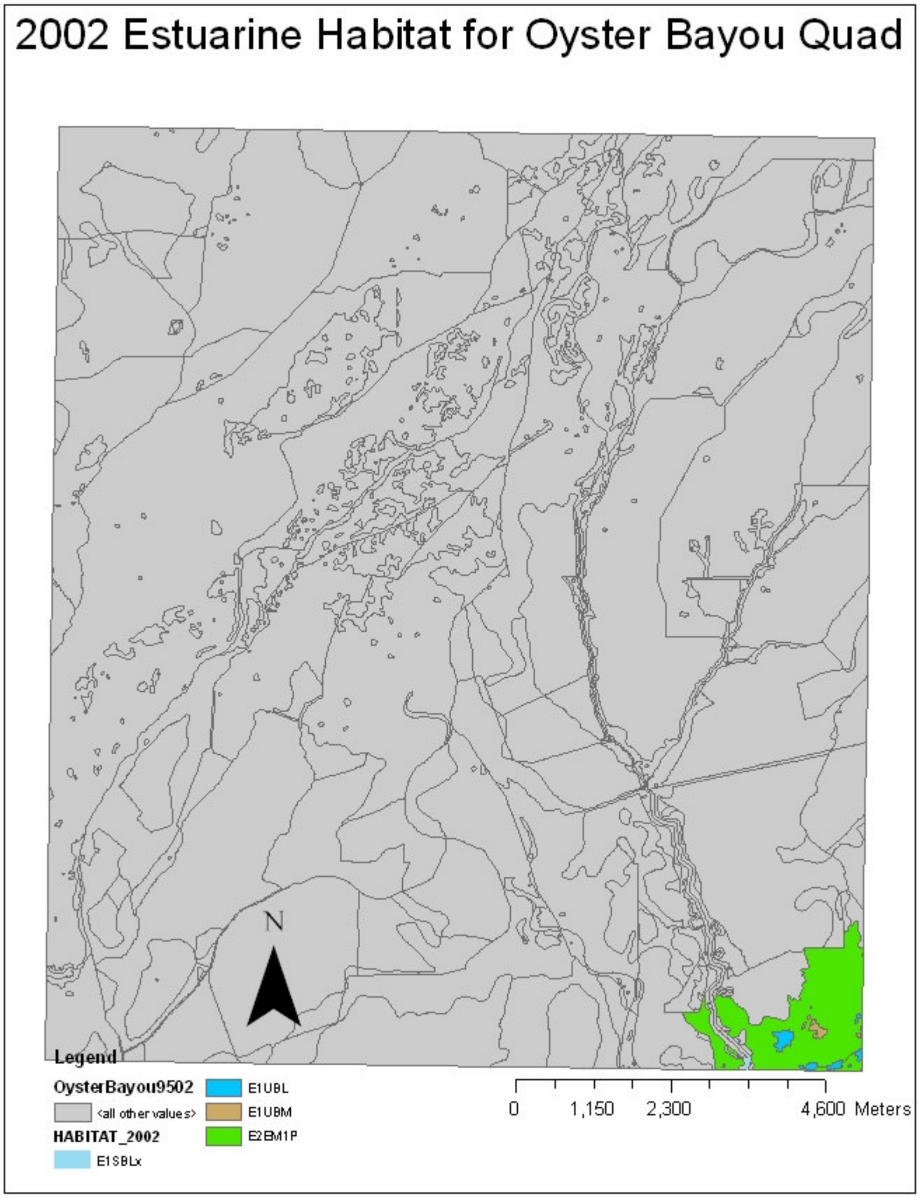
B-18: Morgans Point quad map



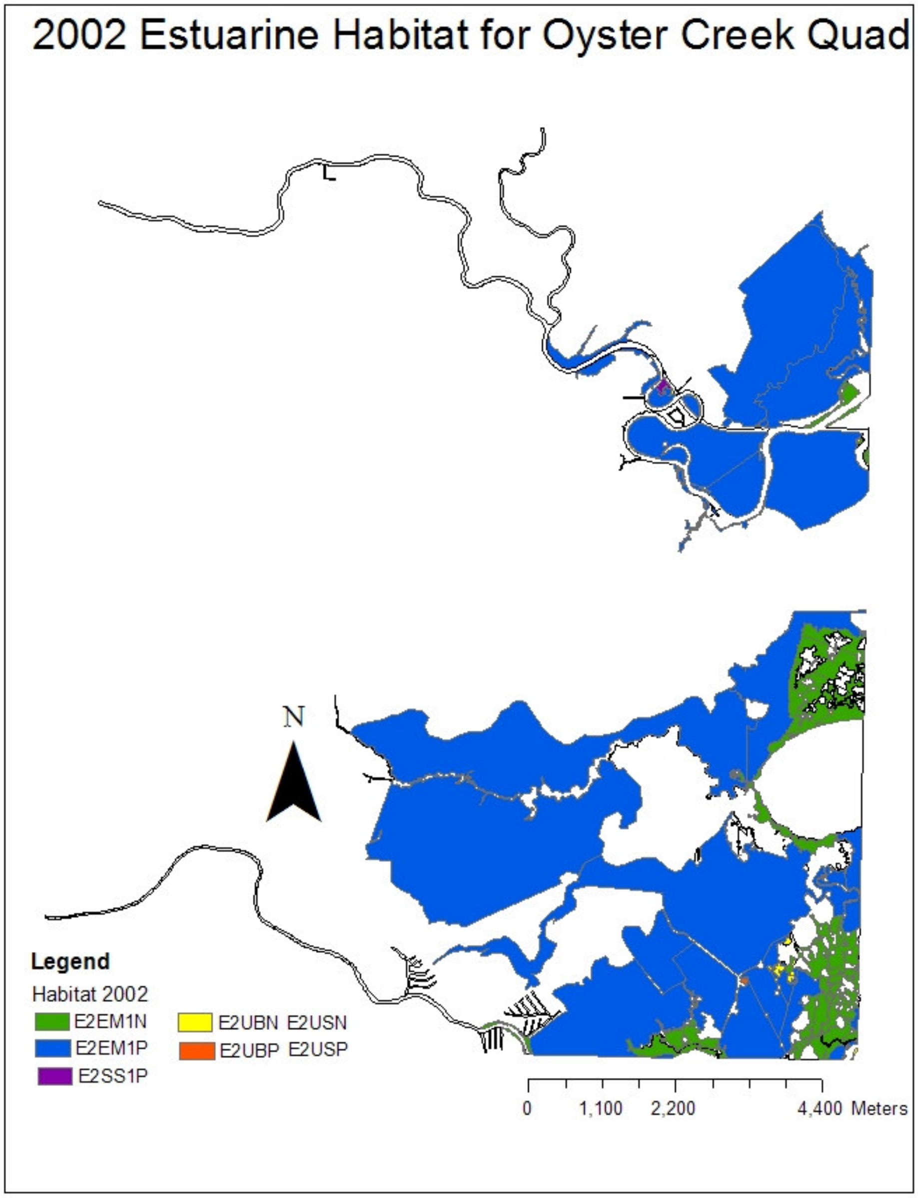
B-19: Oak Island quad map



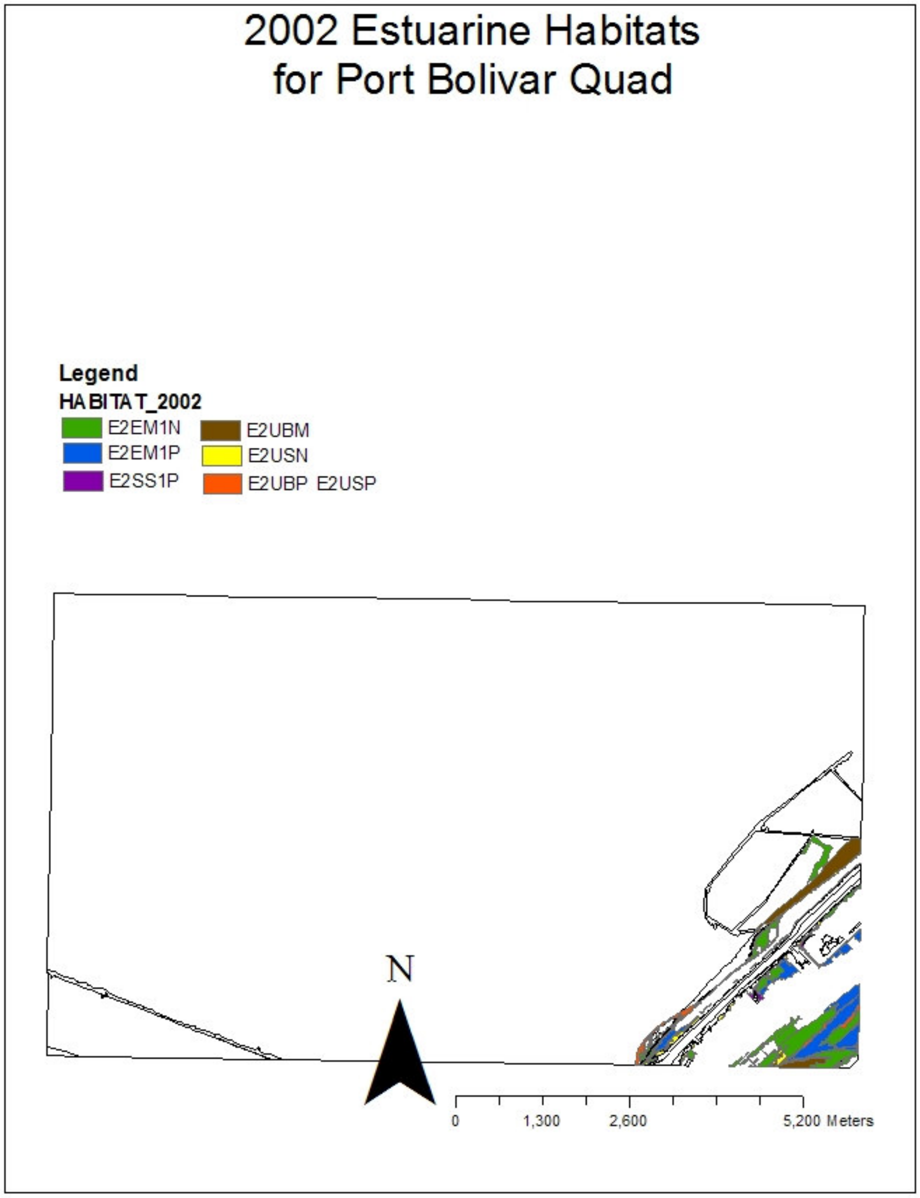
B-20: Oyster Bayou quad map



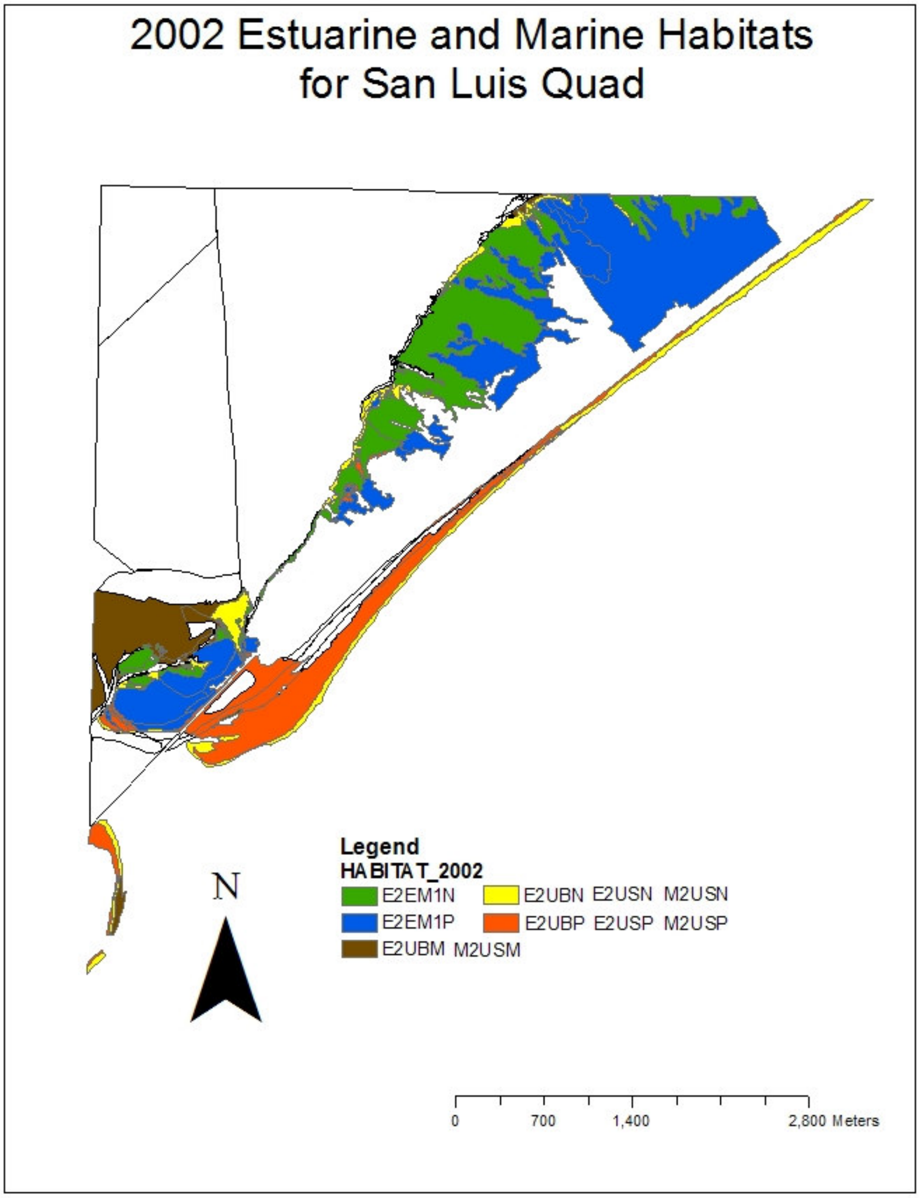
B-21: Oyster Creek quad map



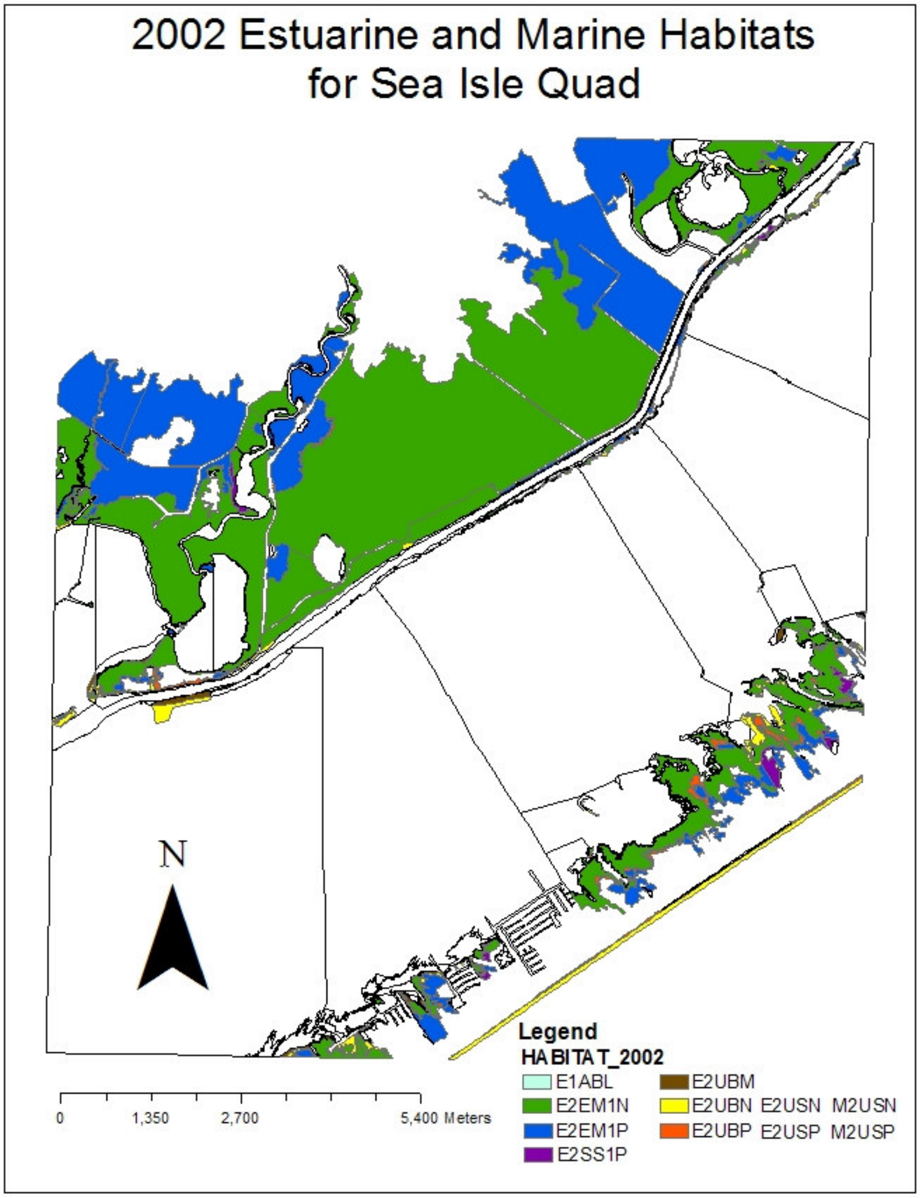
B-22: Port Bolivar quad map



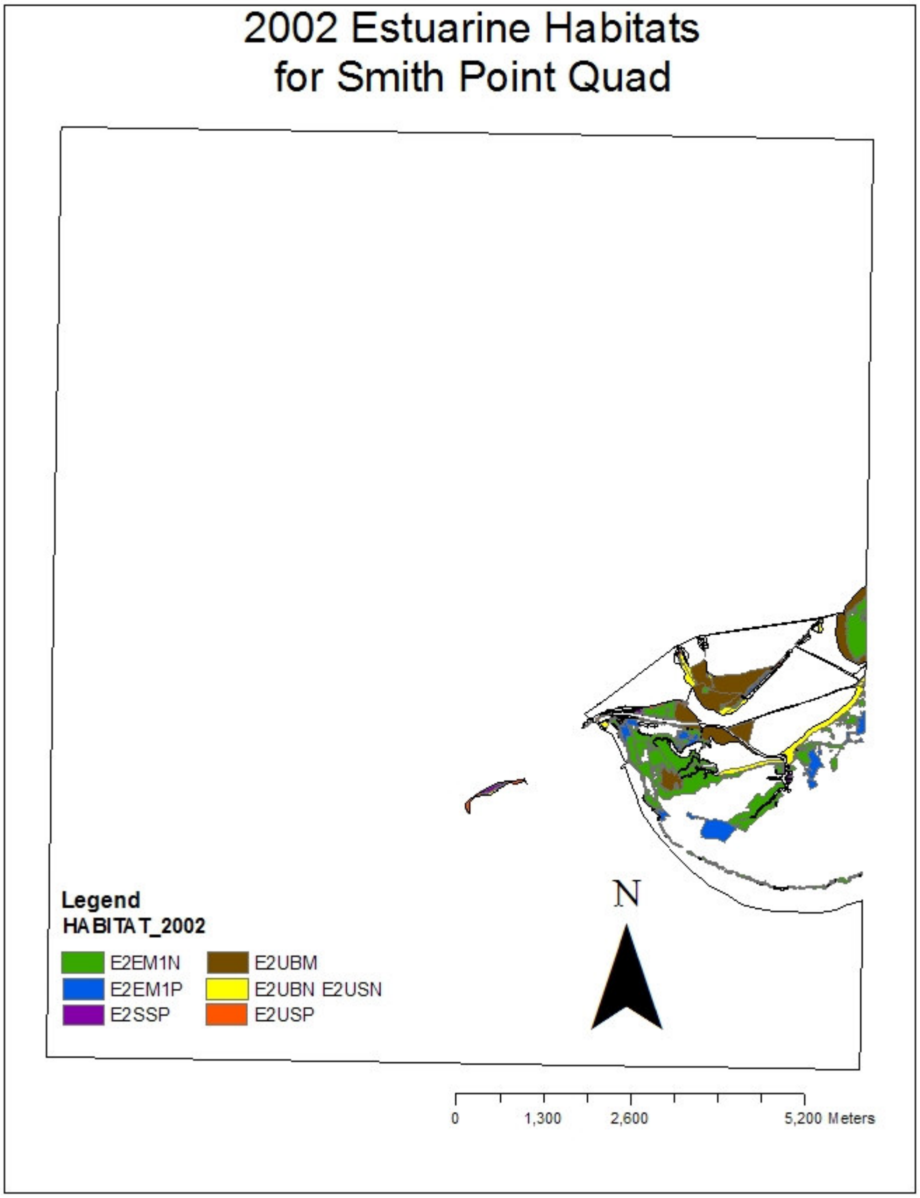
B-23: San Luis quad map



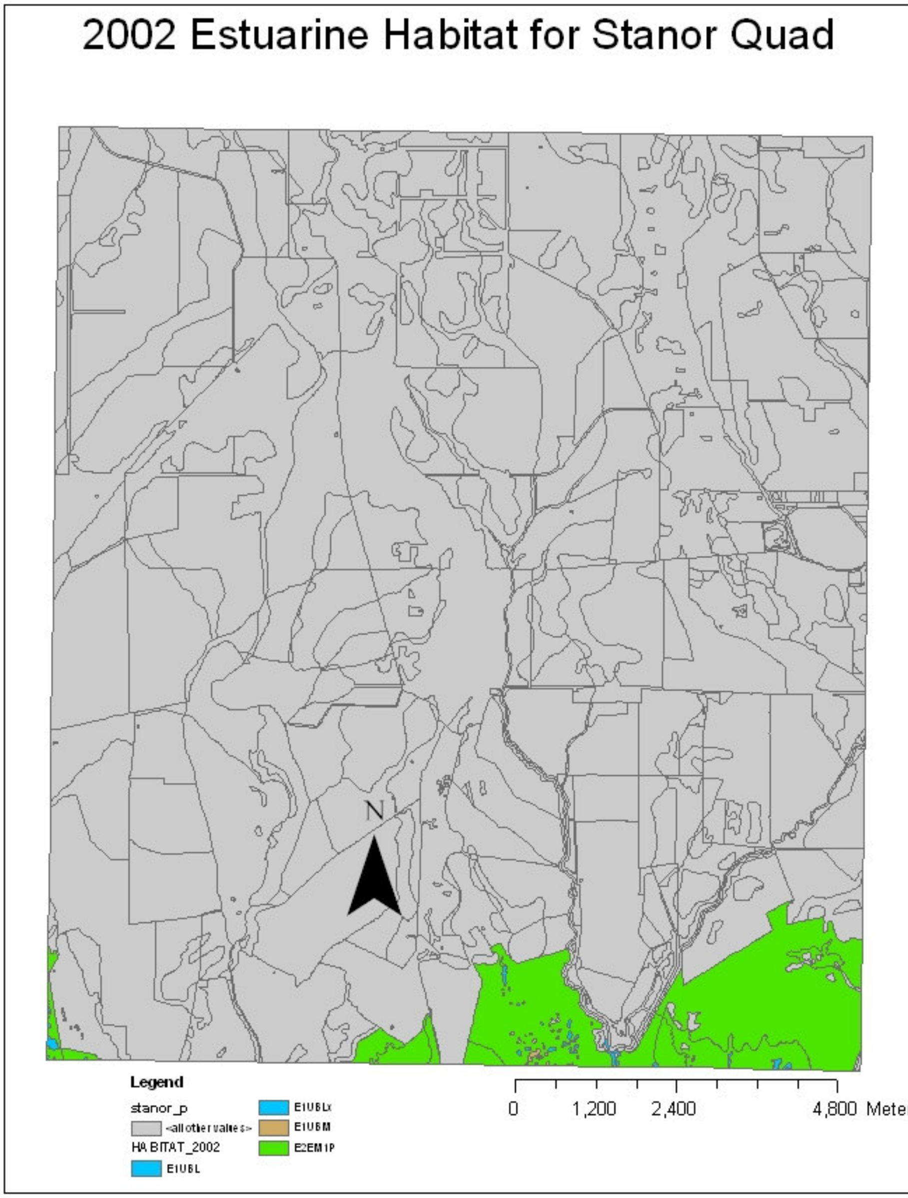
B-24: Sea Isle quad map



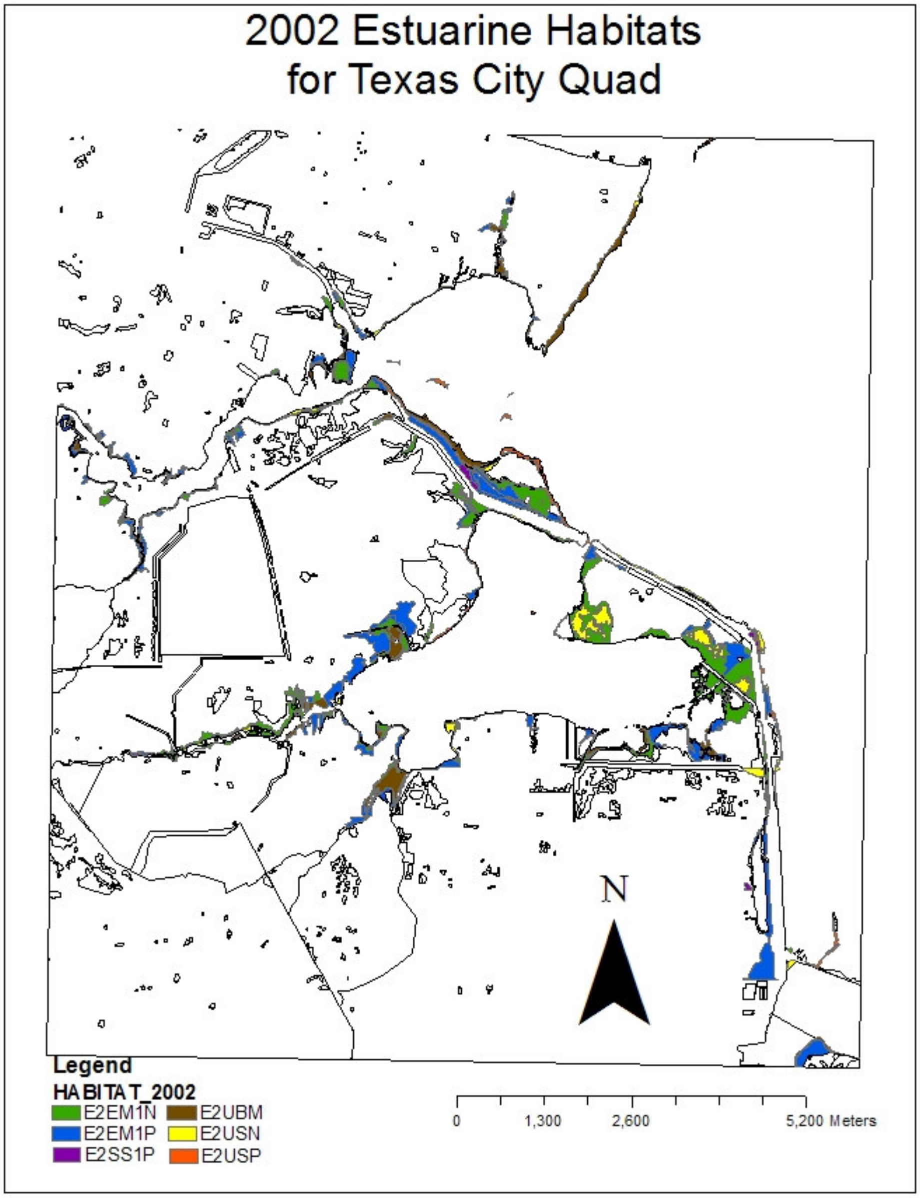
B-25: Smith Point quad map



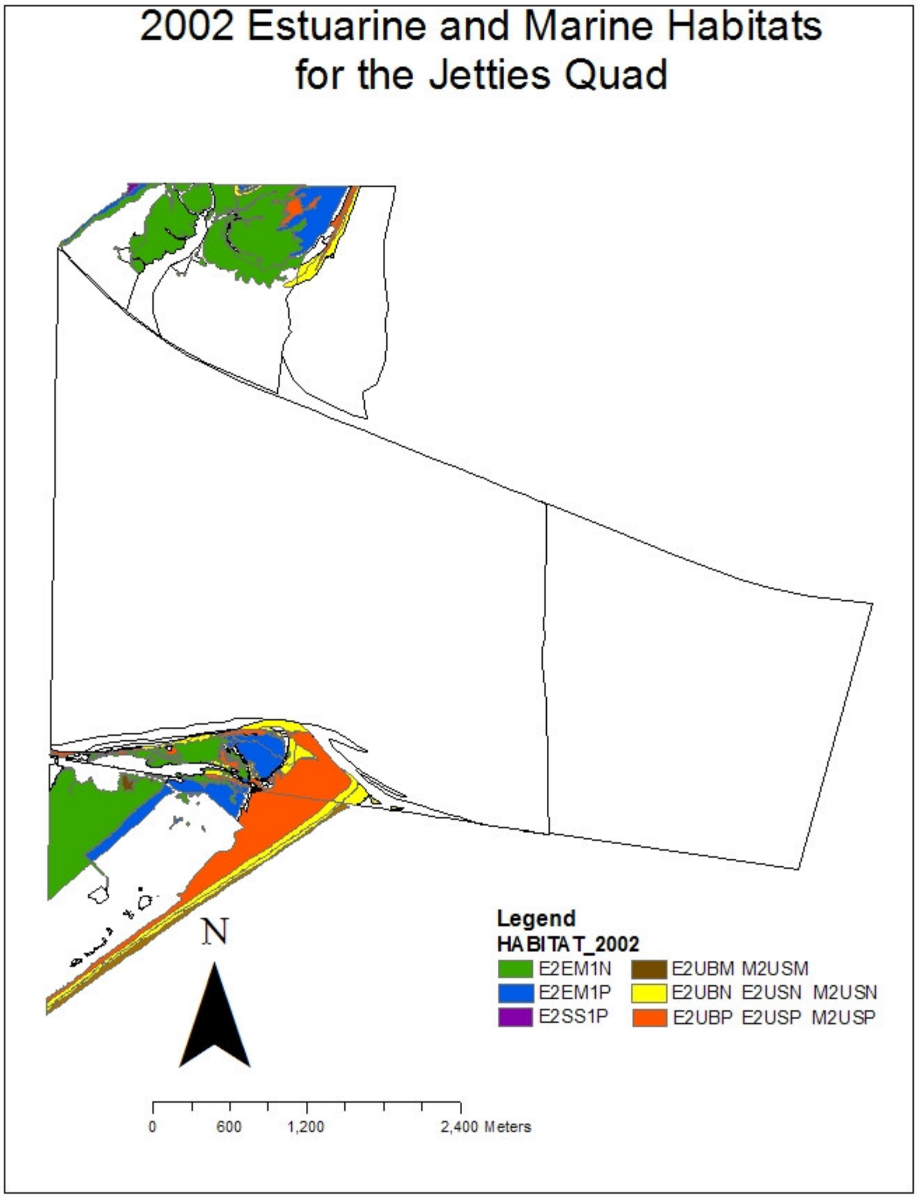
B-26: Stanislind Reservoir quad map



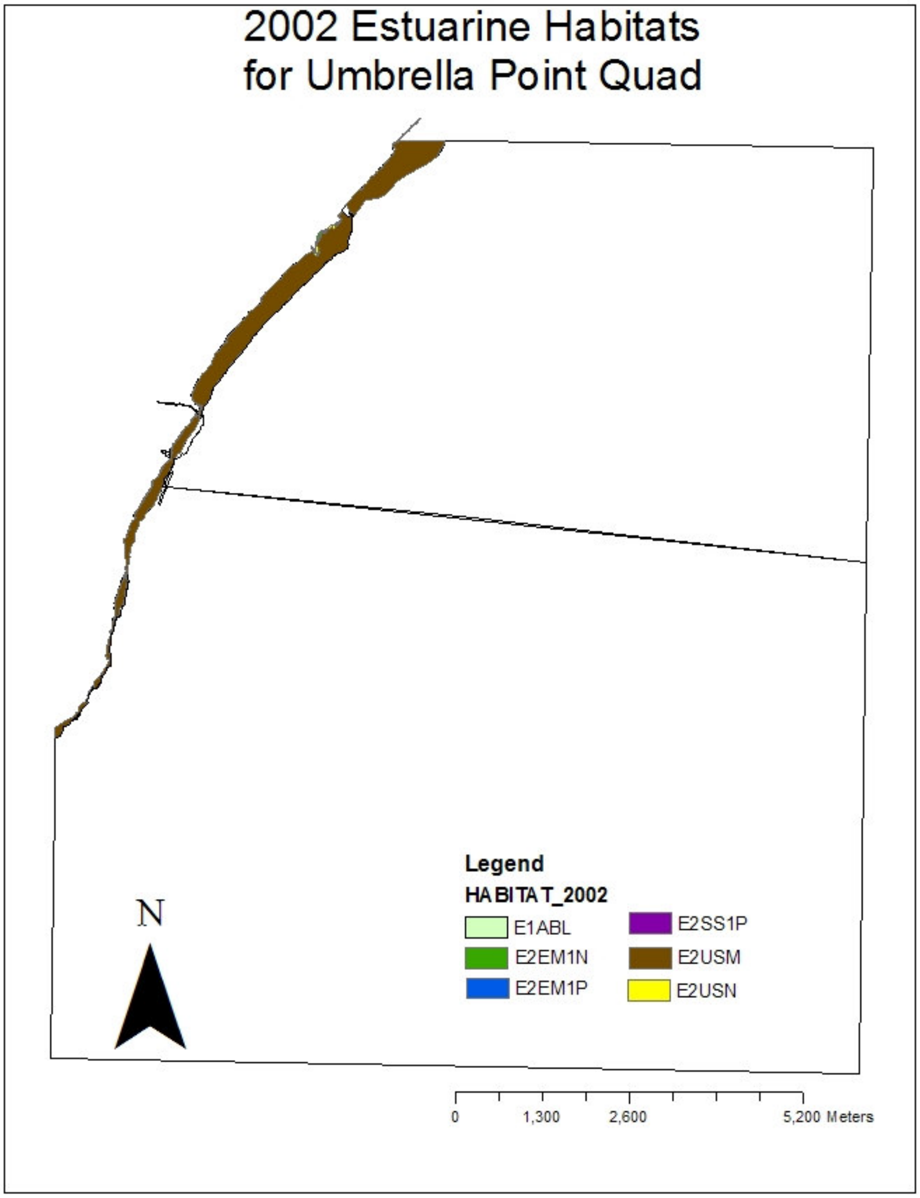
B-27: Texas City quad map



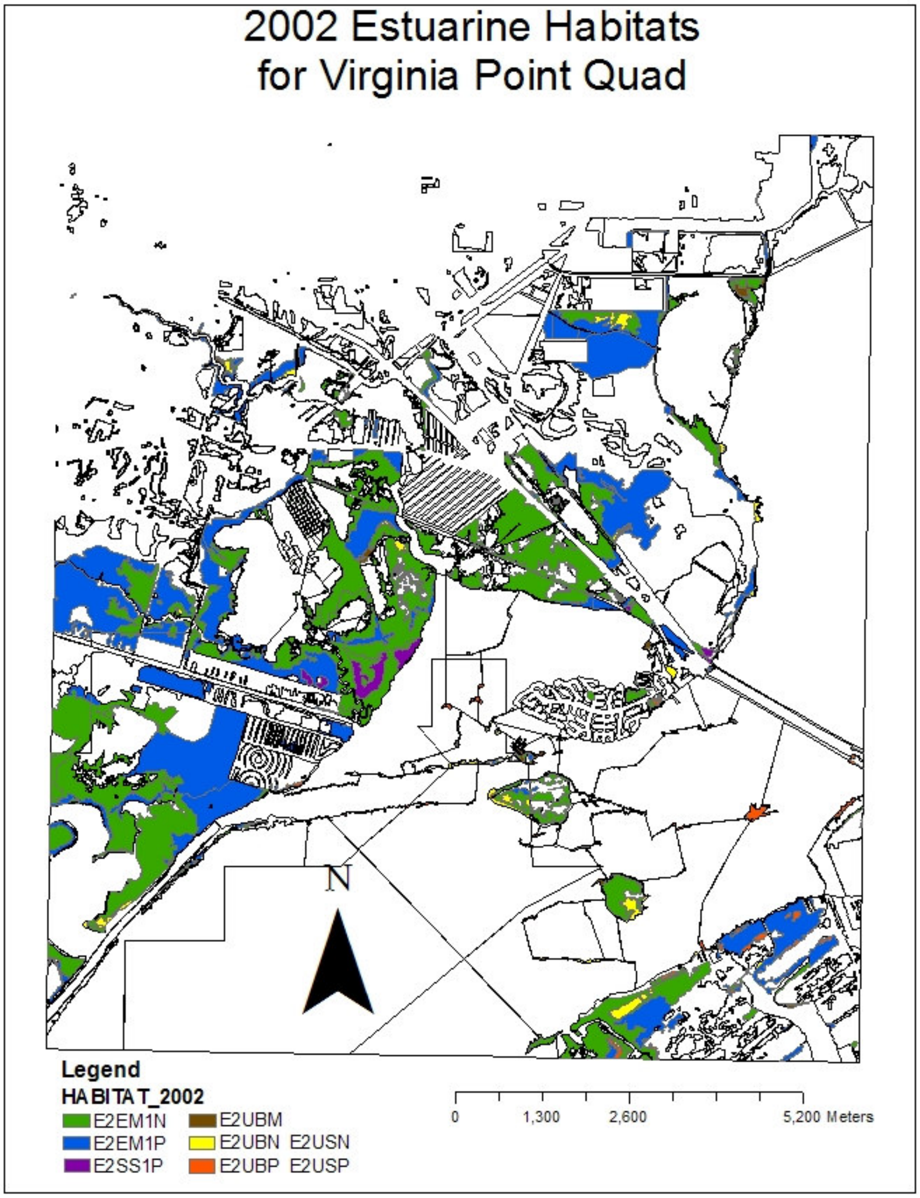
B-28: The Jetties quad map



B-29: Umbrella Point quad map



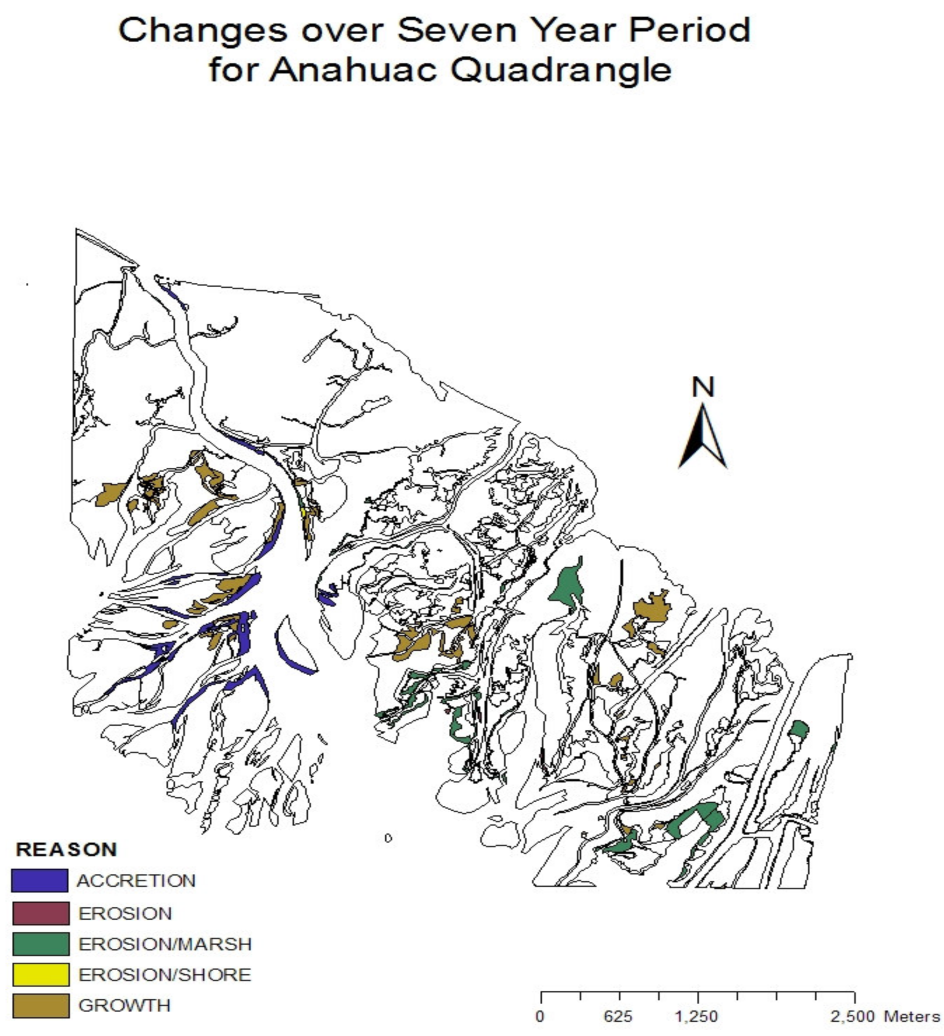
B-30: Virginia Point quad map



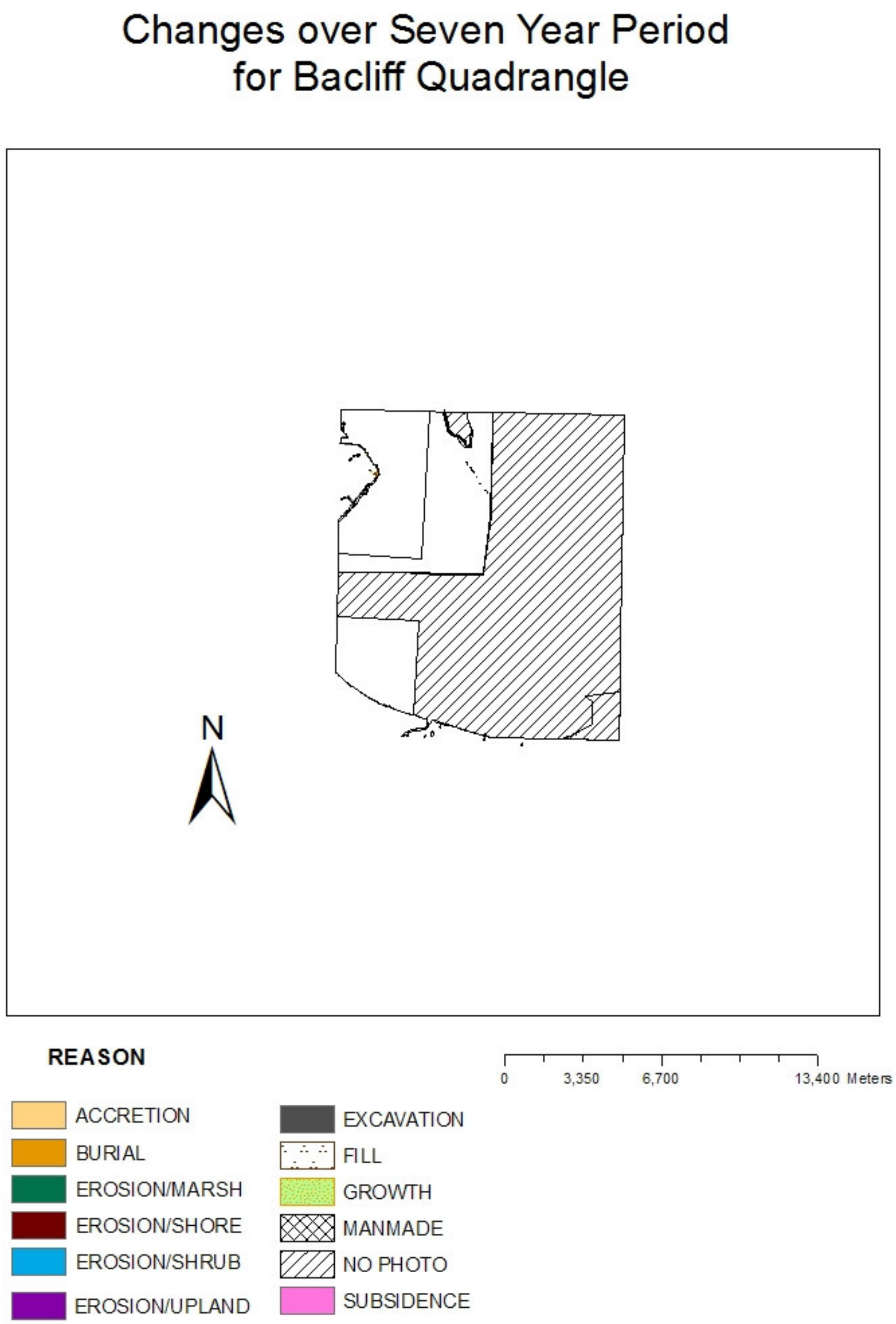
APPENDIX C

MAPS SHOWING THE CHANGES THAT OCCURRED IN EACH QUAD OVER THE SEVEN -YEAR PERIOD OF 1995-2002

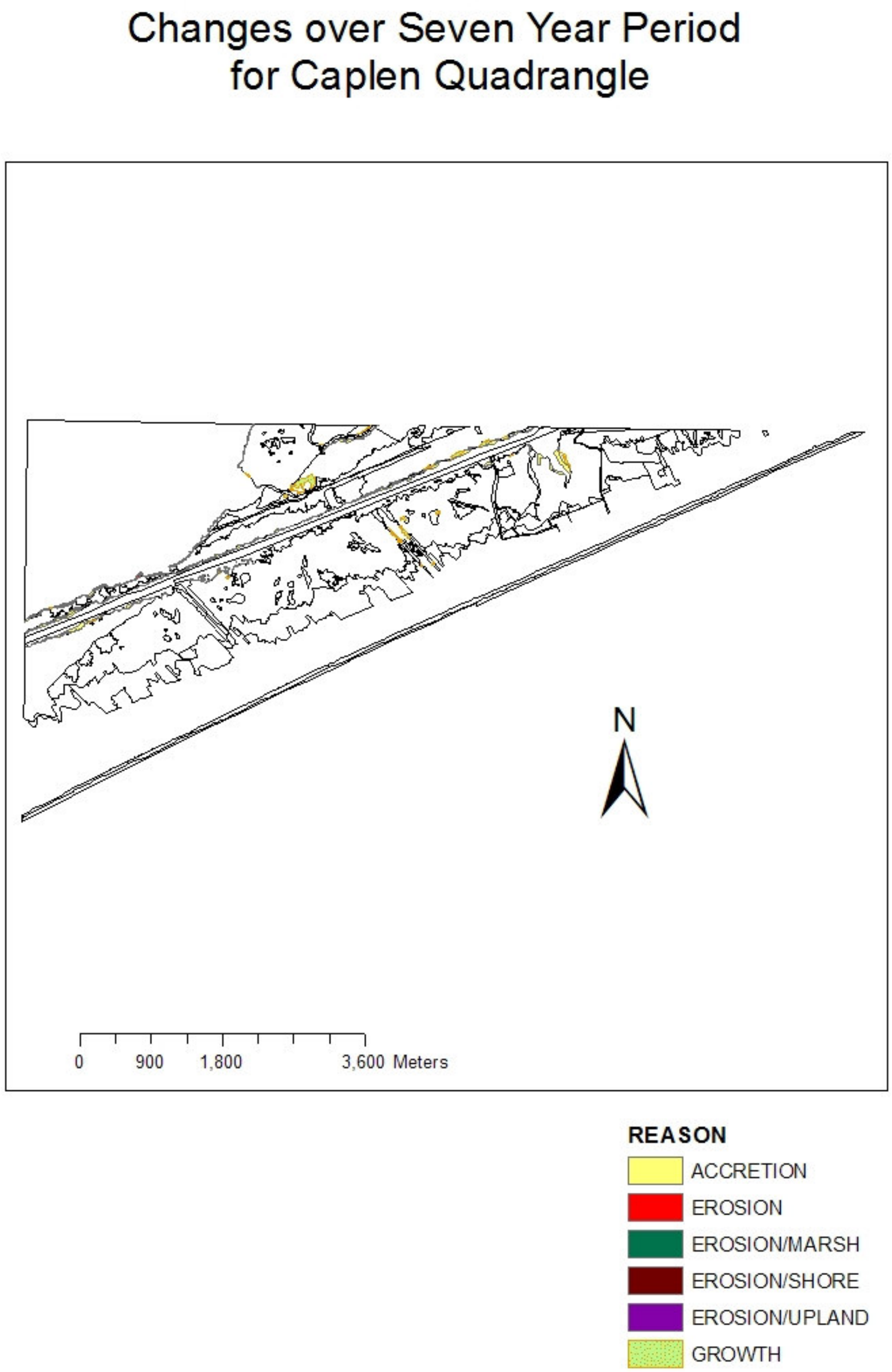
C-1: Anahuac quad changes map



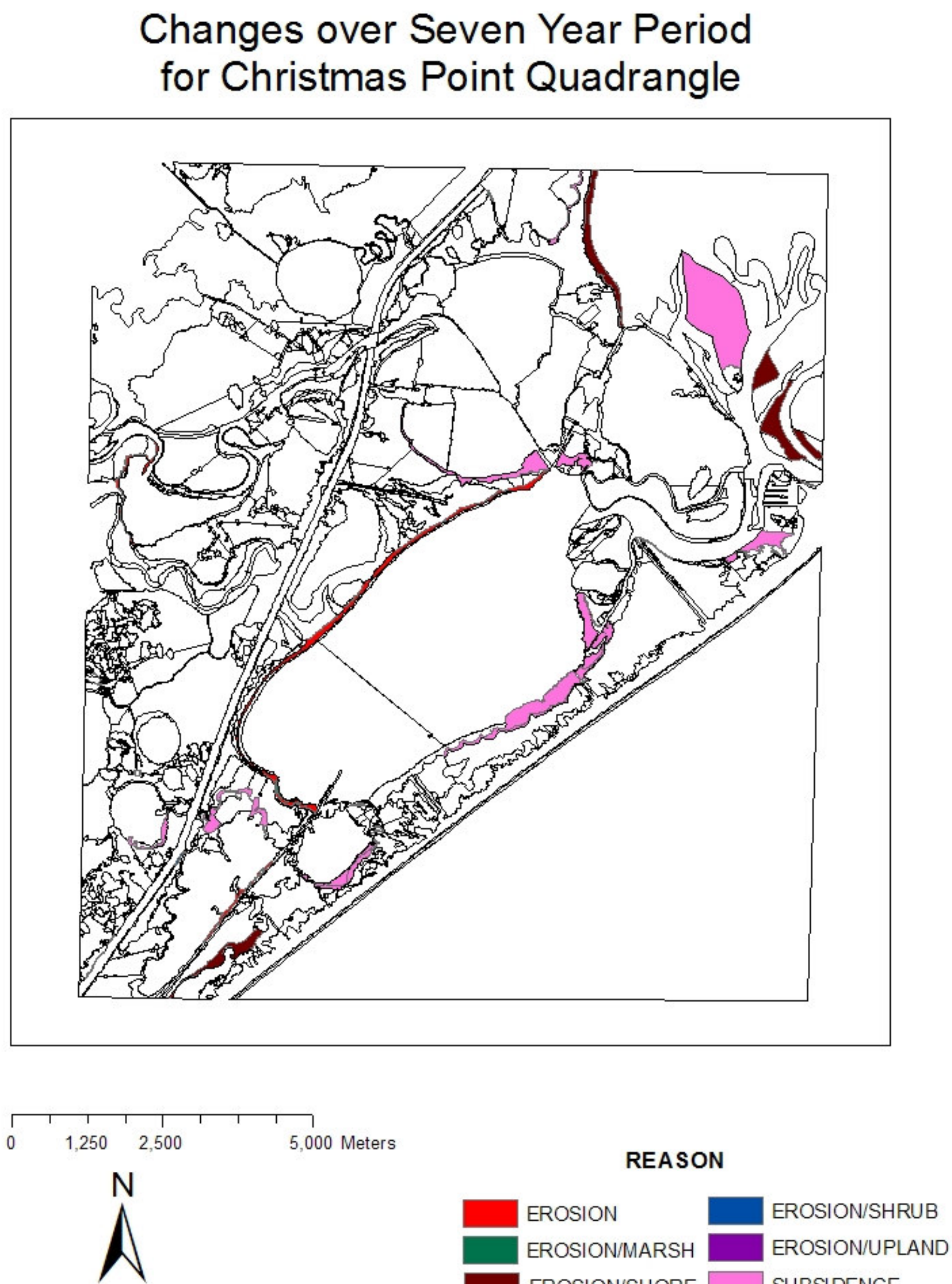
C-2: Bacliff quad changes map



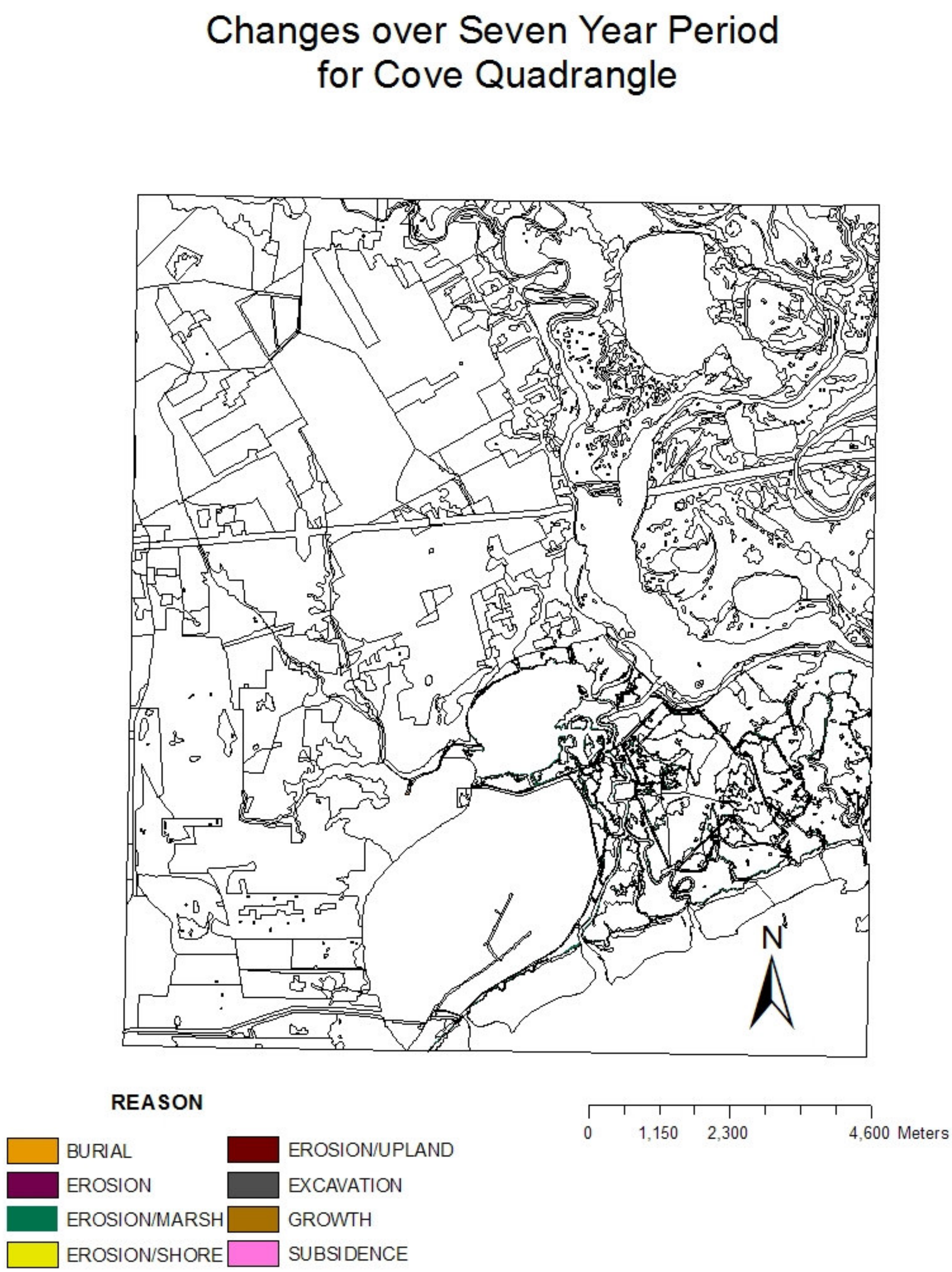
C-3: Caplen quad changes map



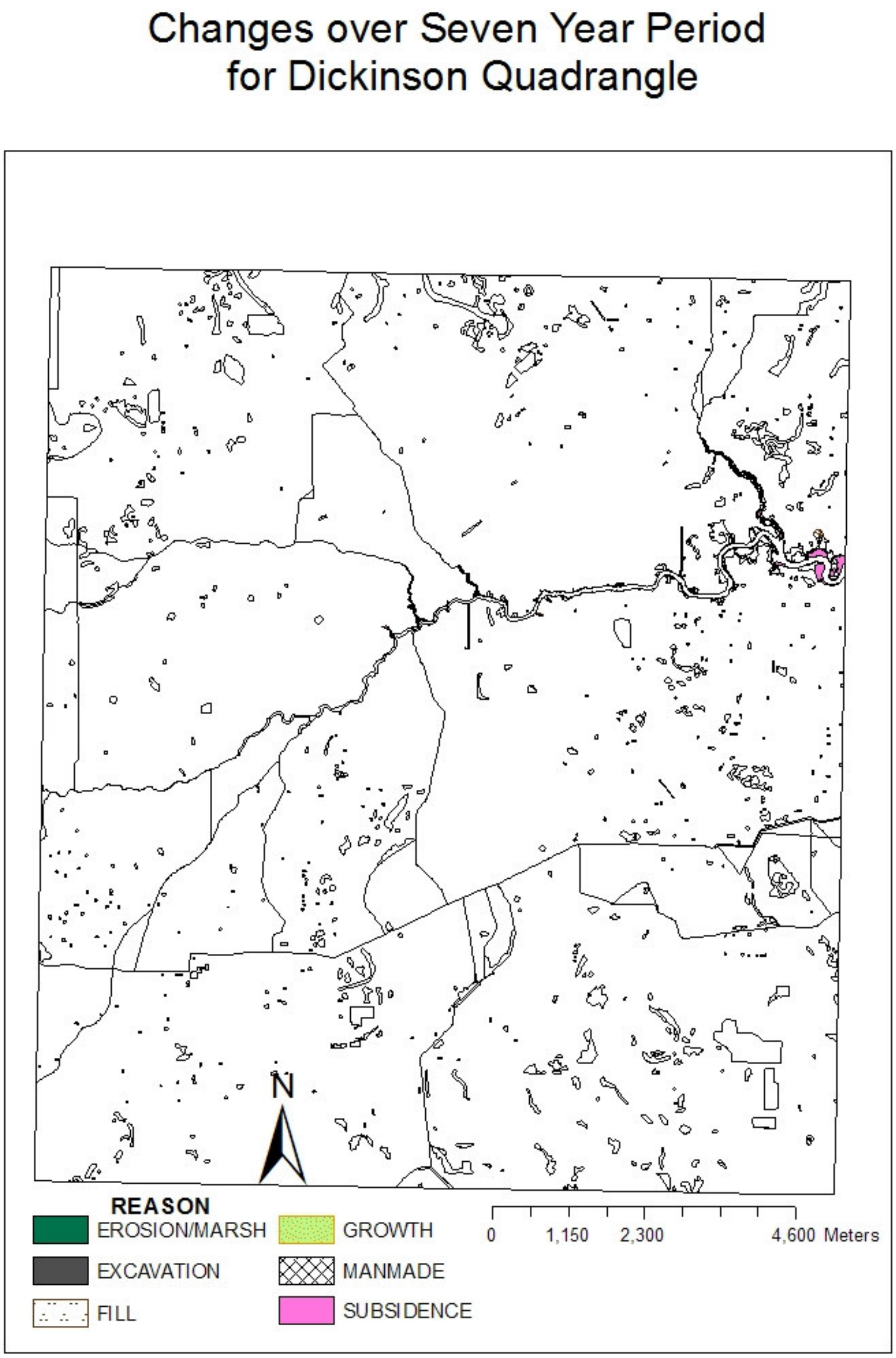
C-5: Christmas Point quad changes map



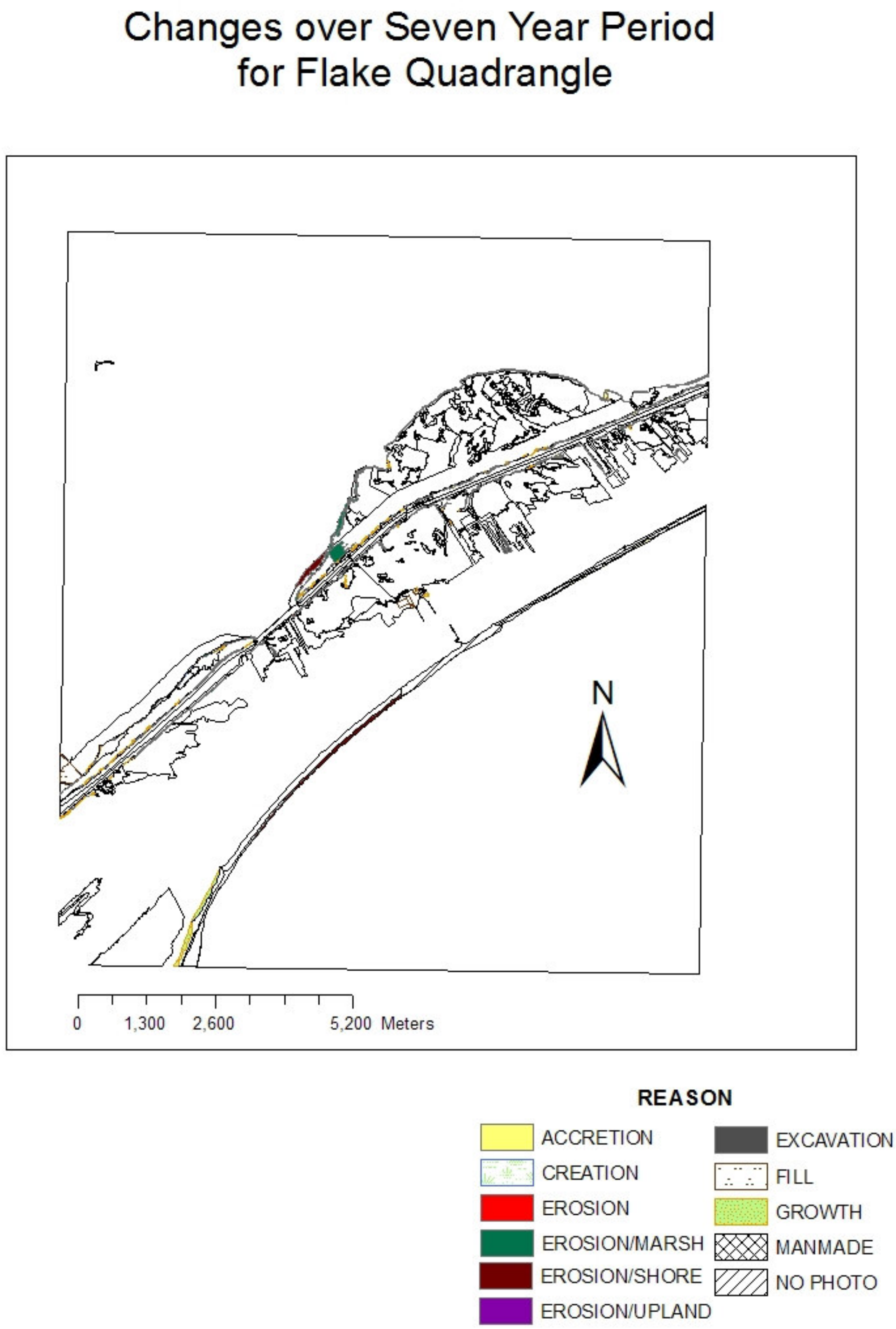
C-6: Cove quad changes map



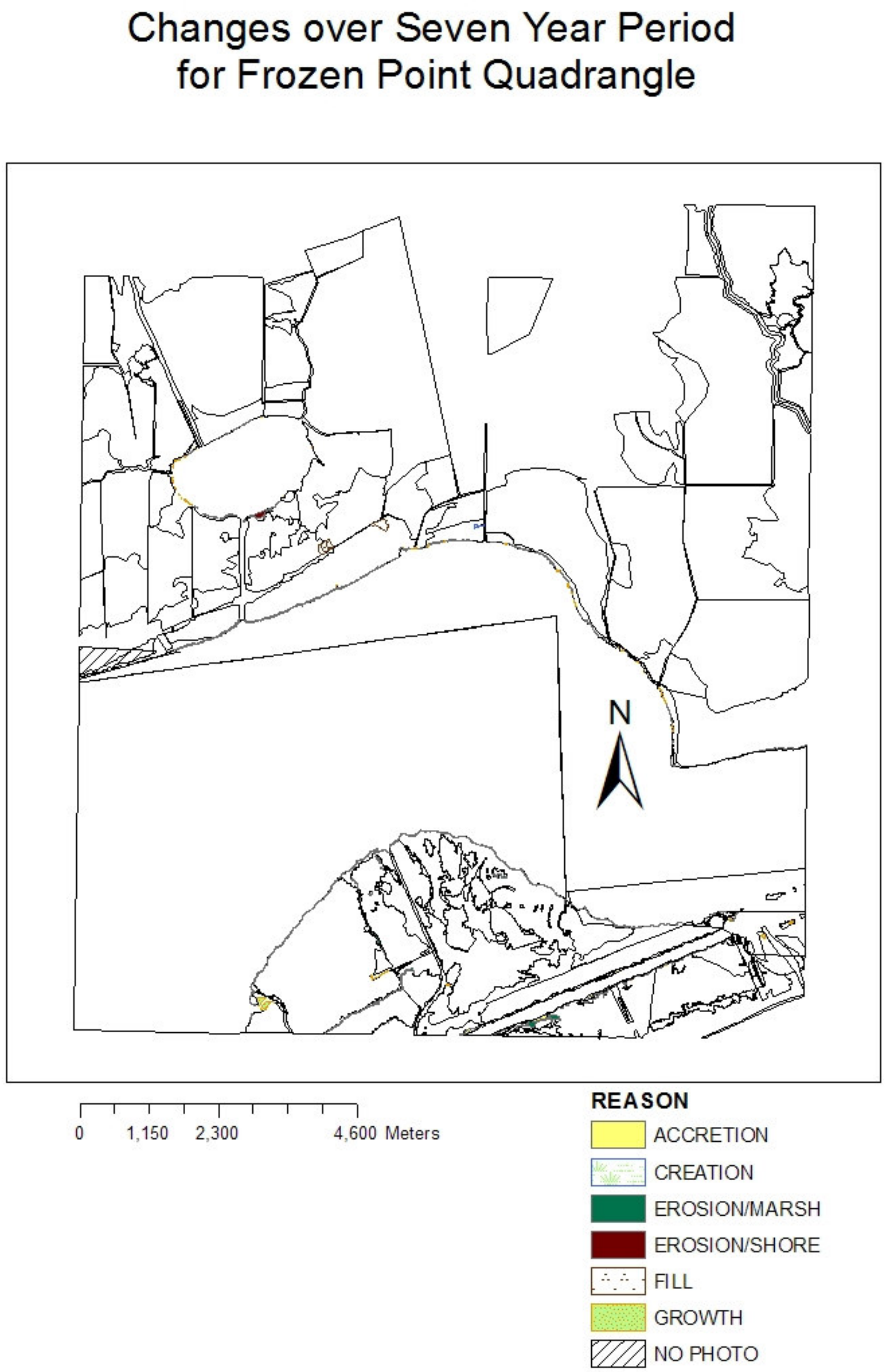
C-7: Dickinson quad changes map



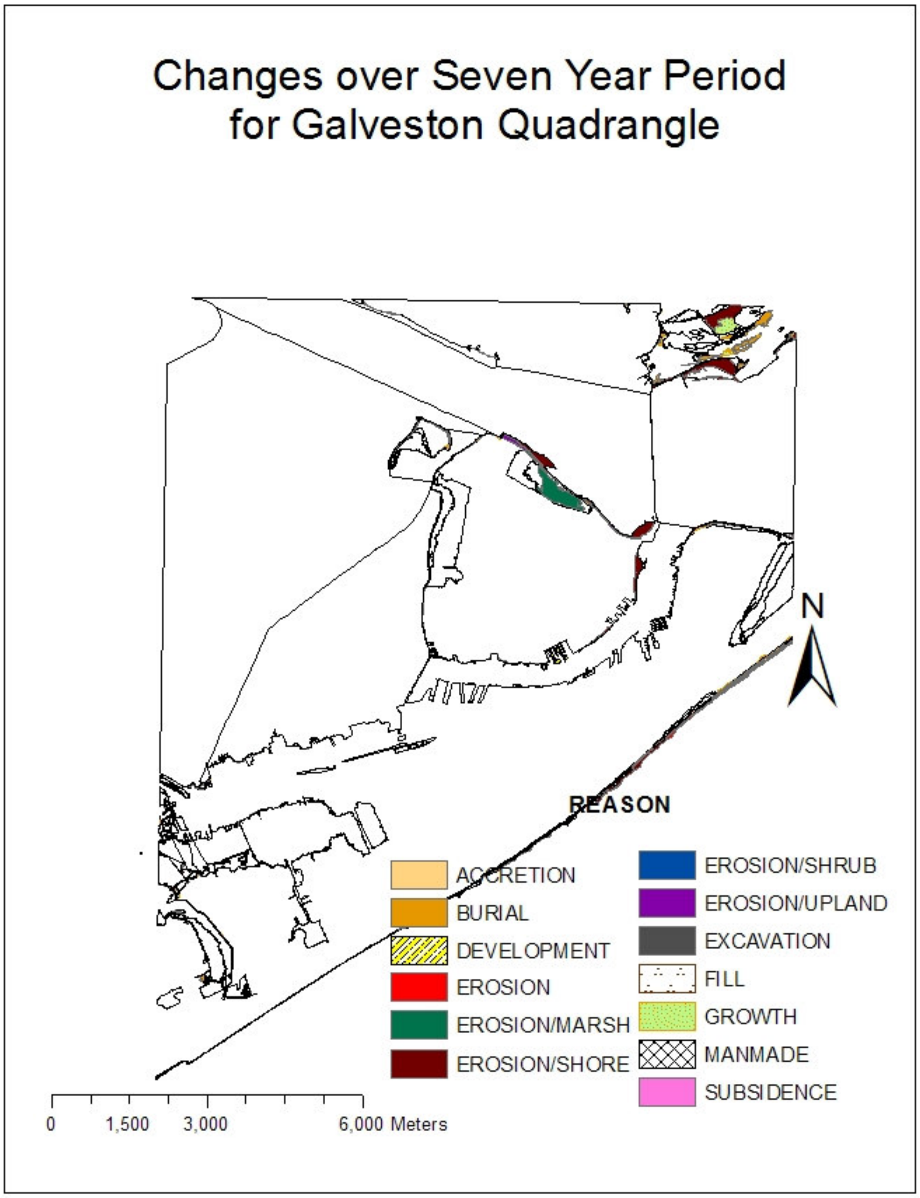
C-8: Flake quad changes map



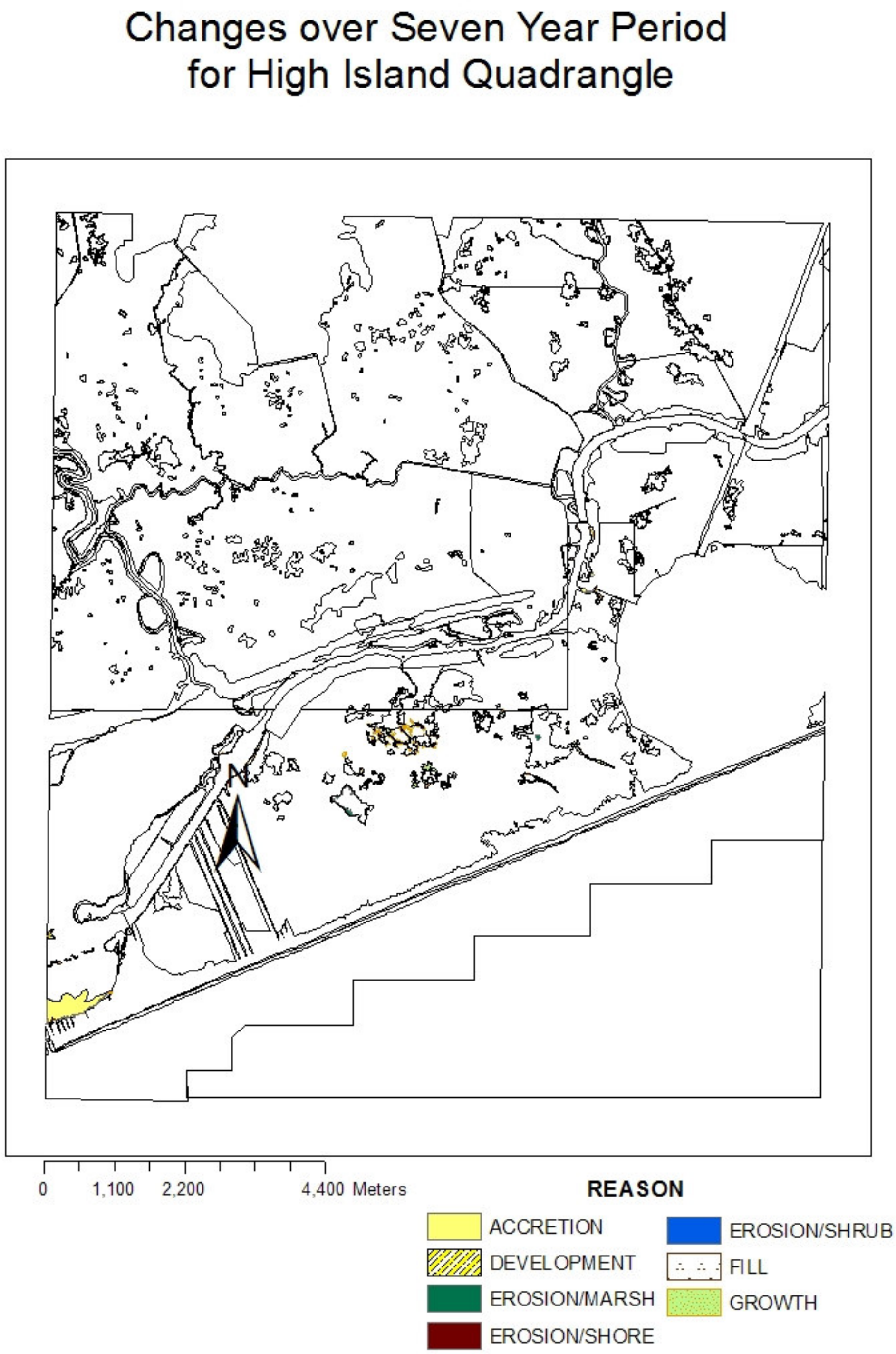
C-9: Frozen Point quad changes map



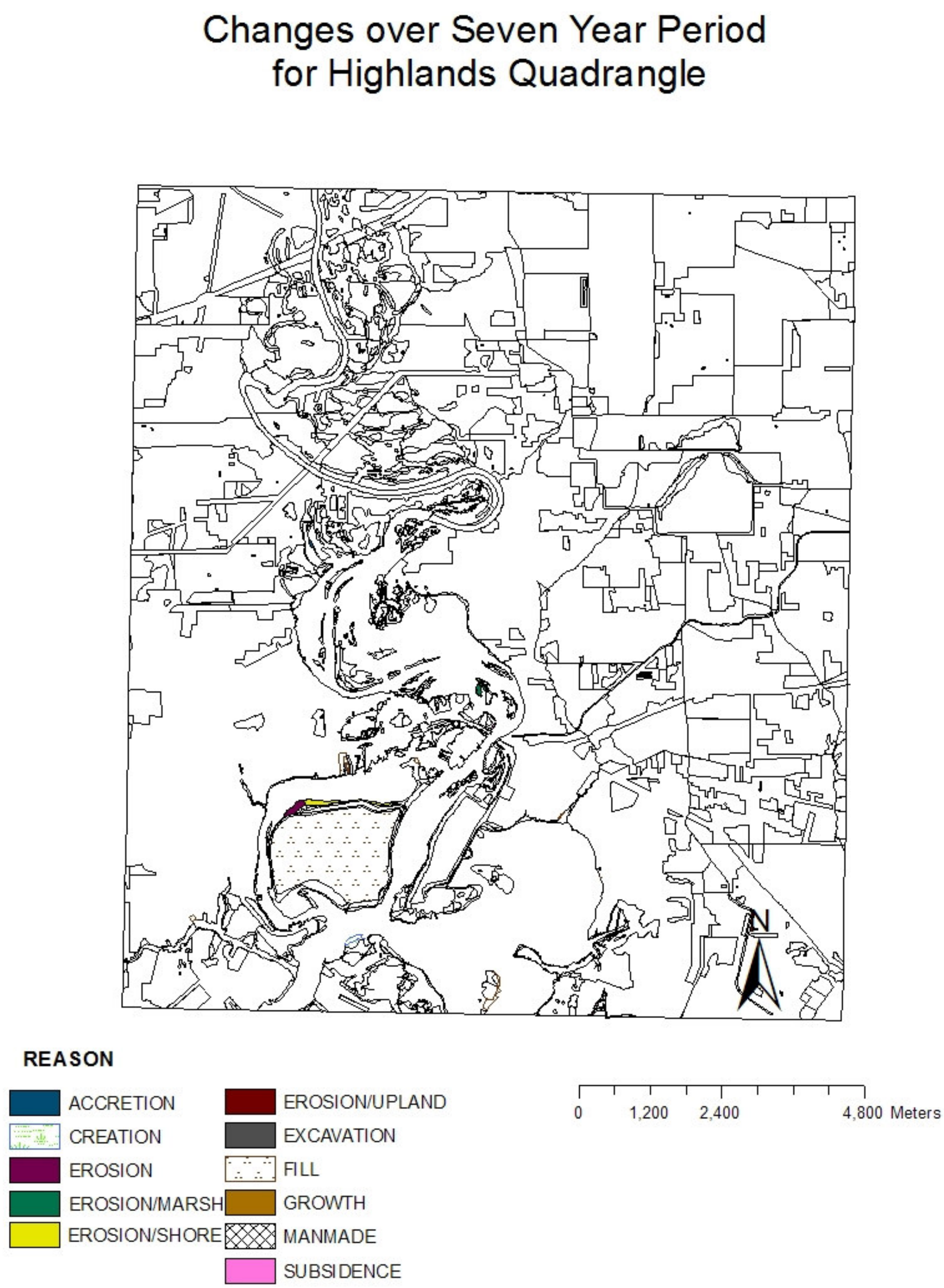
C-10: Galveston quad changes map



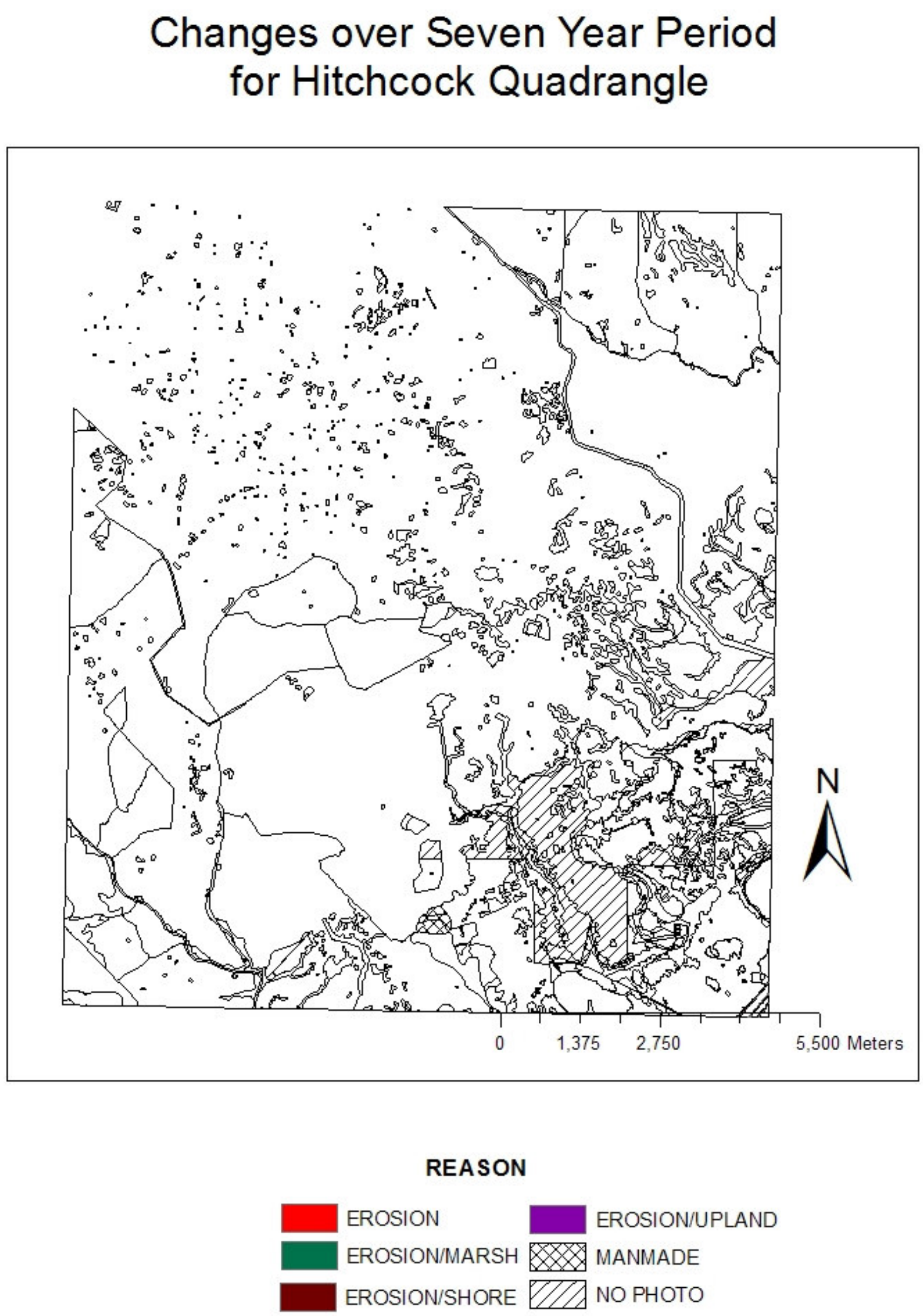
C-11: High Island quad changes map



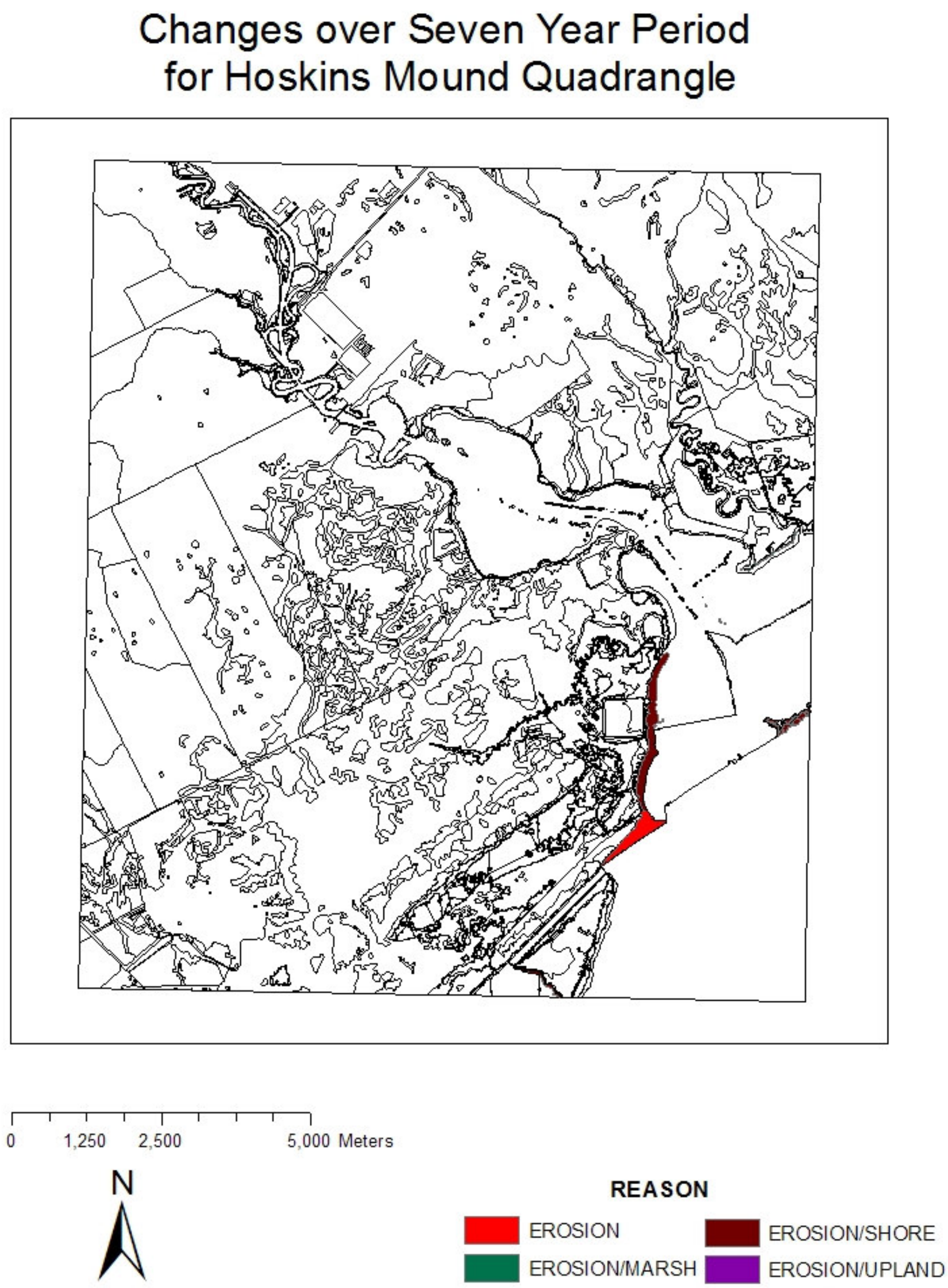
C-12: Highlands quad changes map



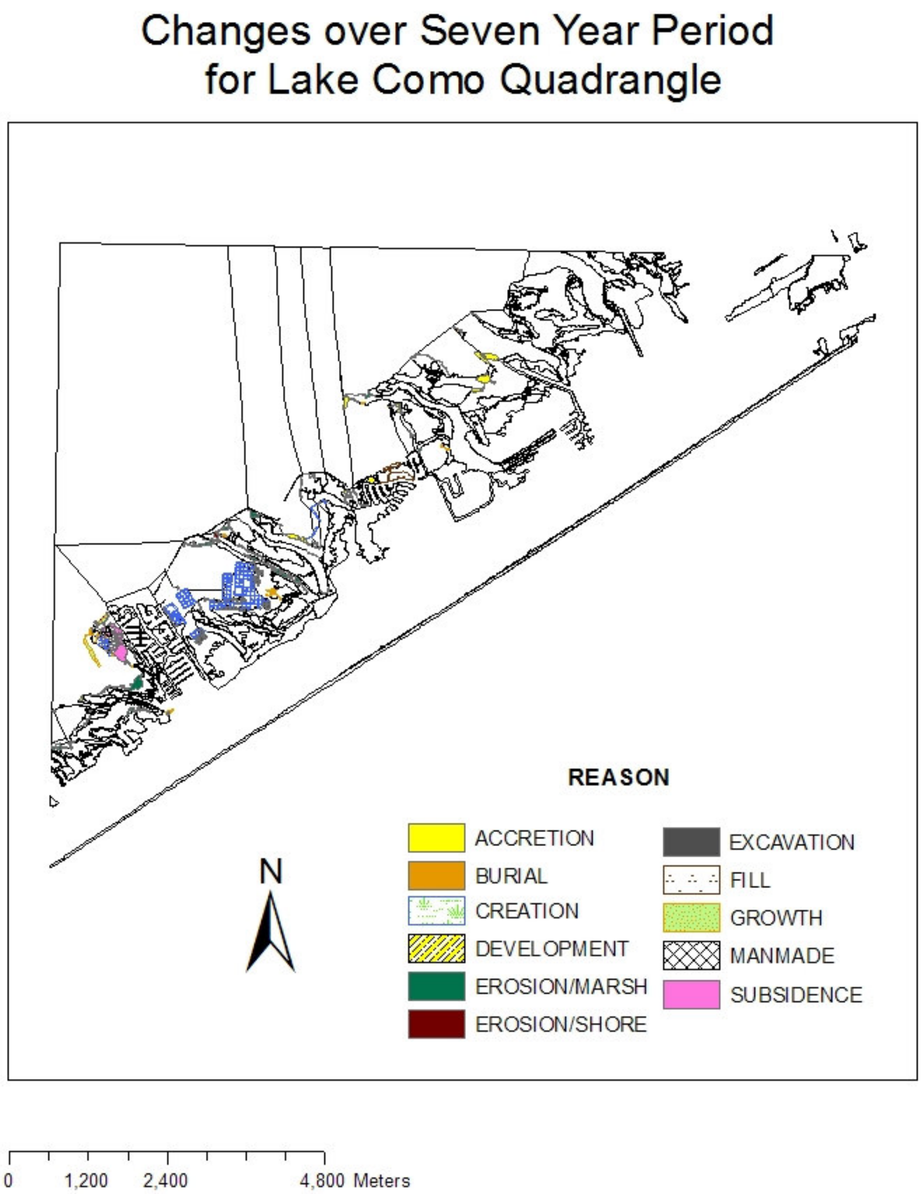
C-13: Hitchcock quad changes map



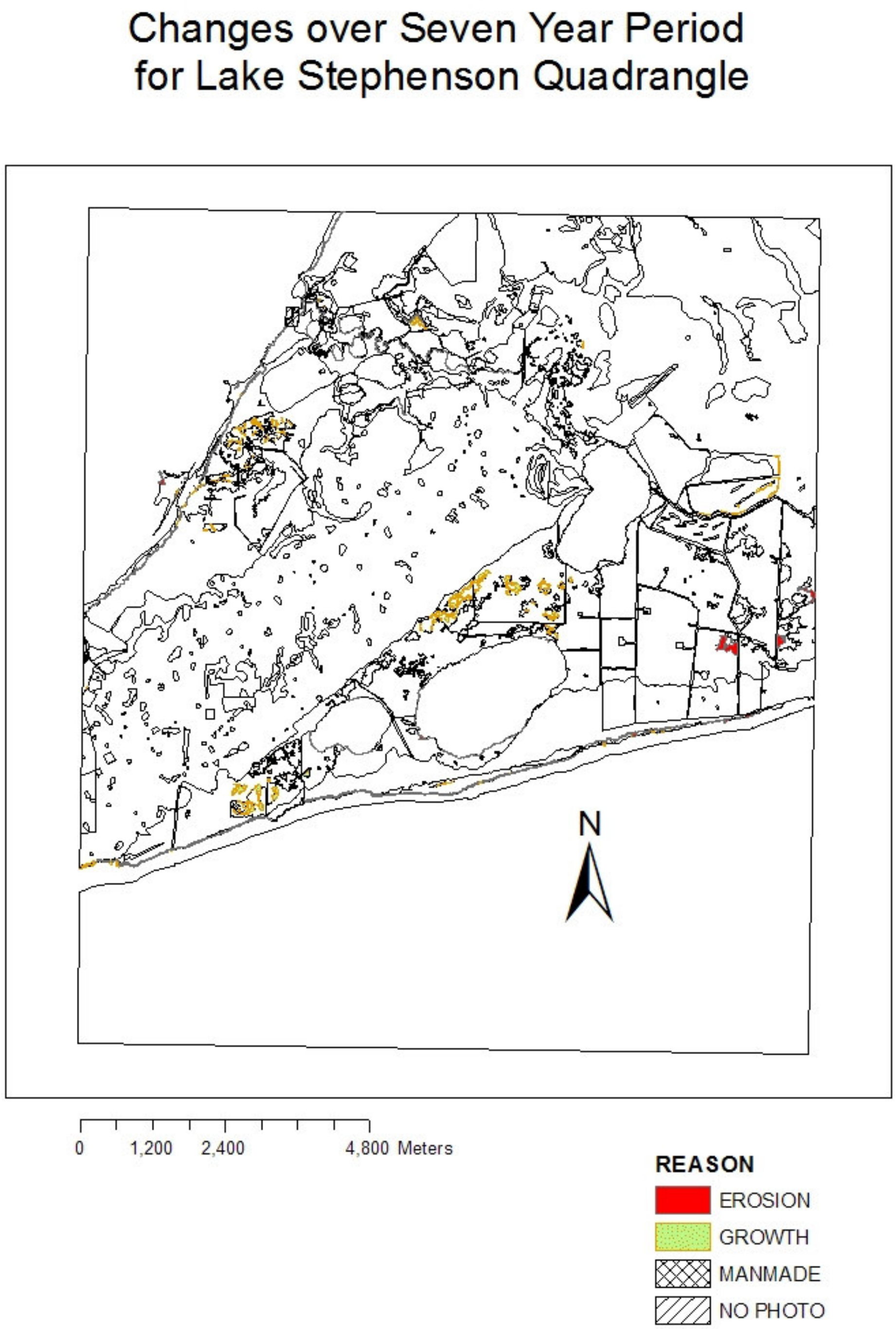
C-14: Hoskins Mound quad changes map



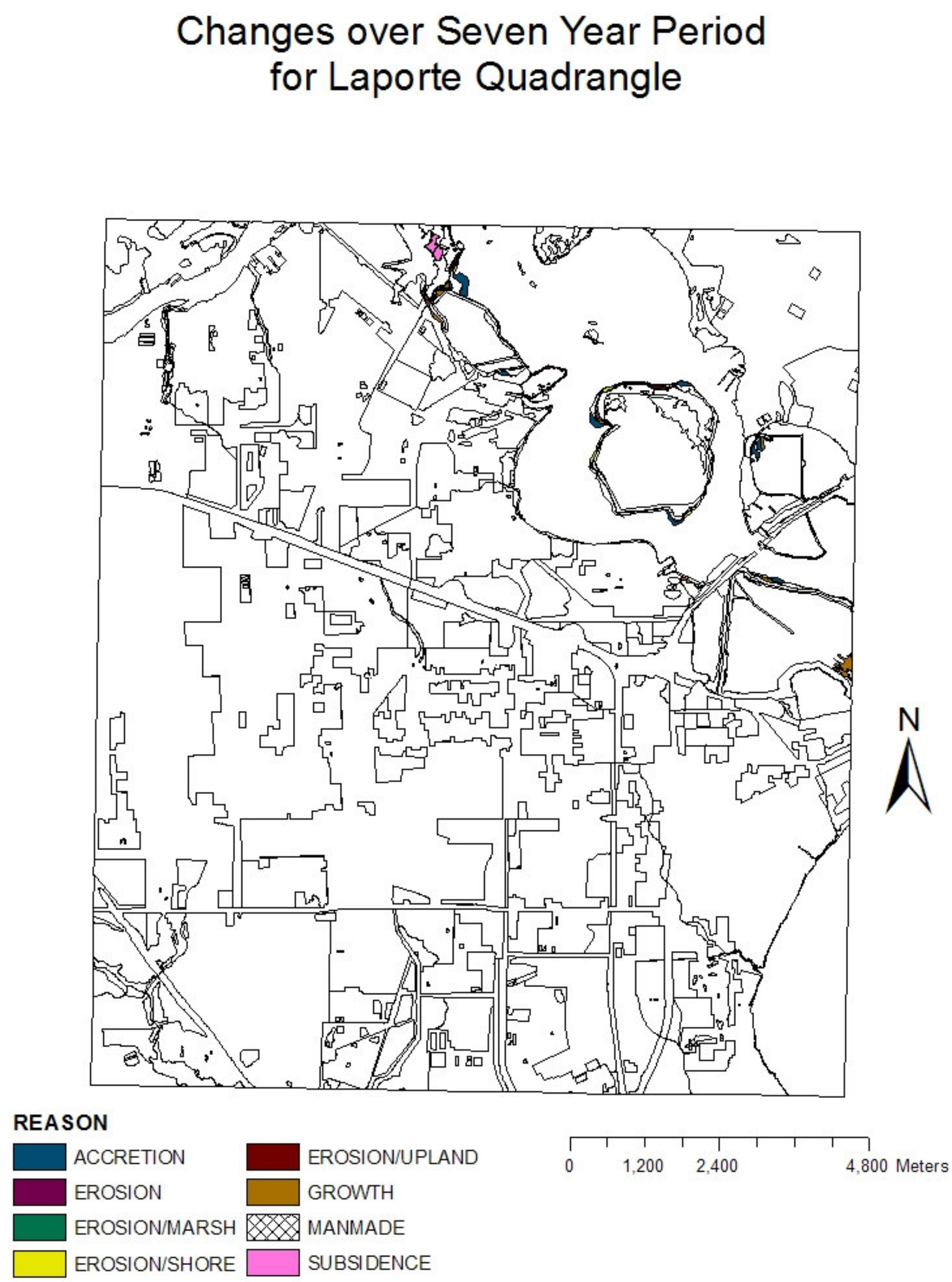
C-15: Lake Como quad changes map



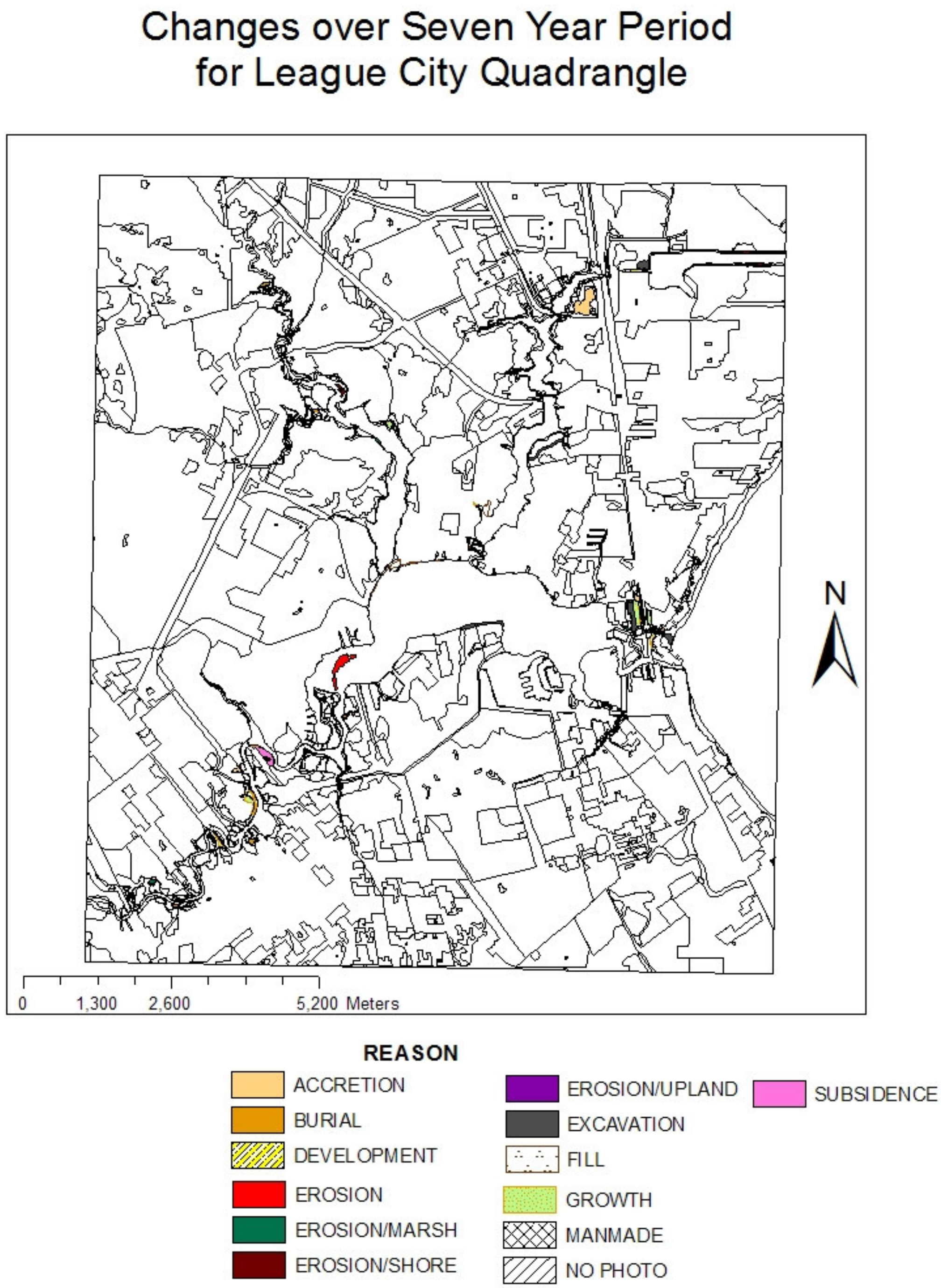
C-16: Lake Stephenson quad changes map



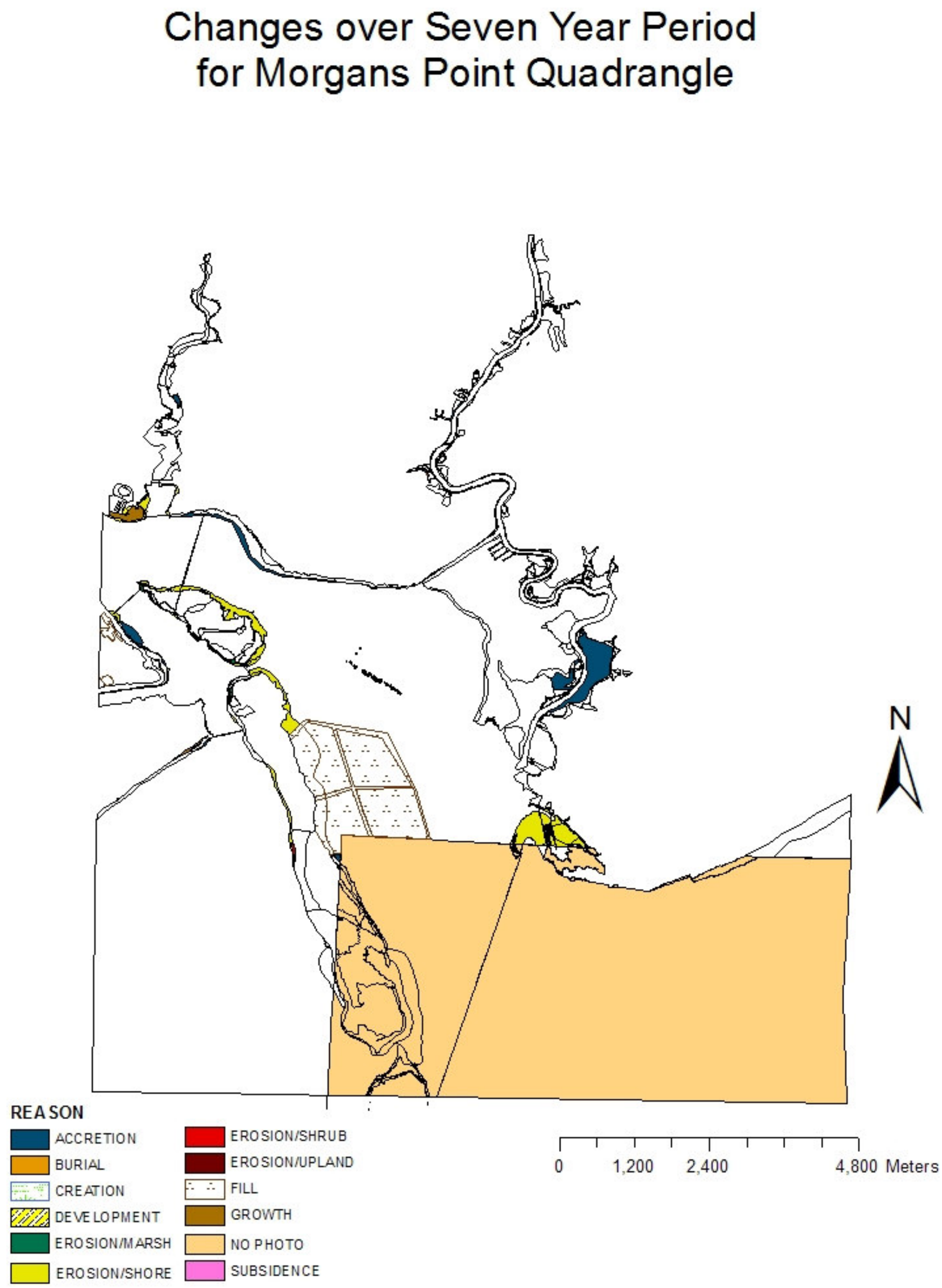
C-17: Laporte quad changes amp



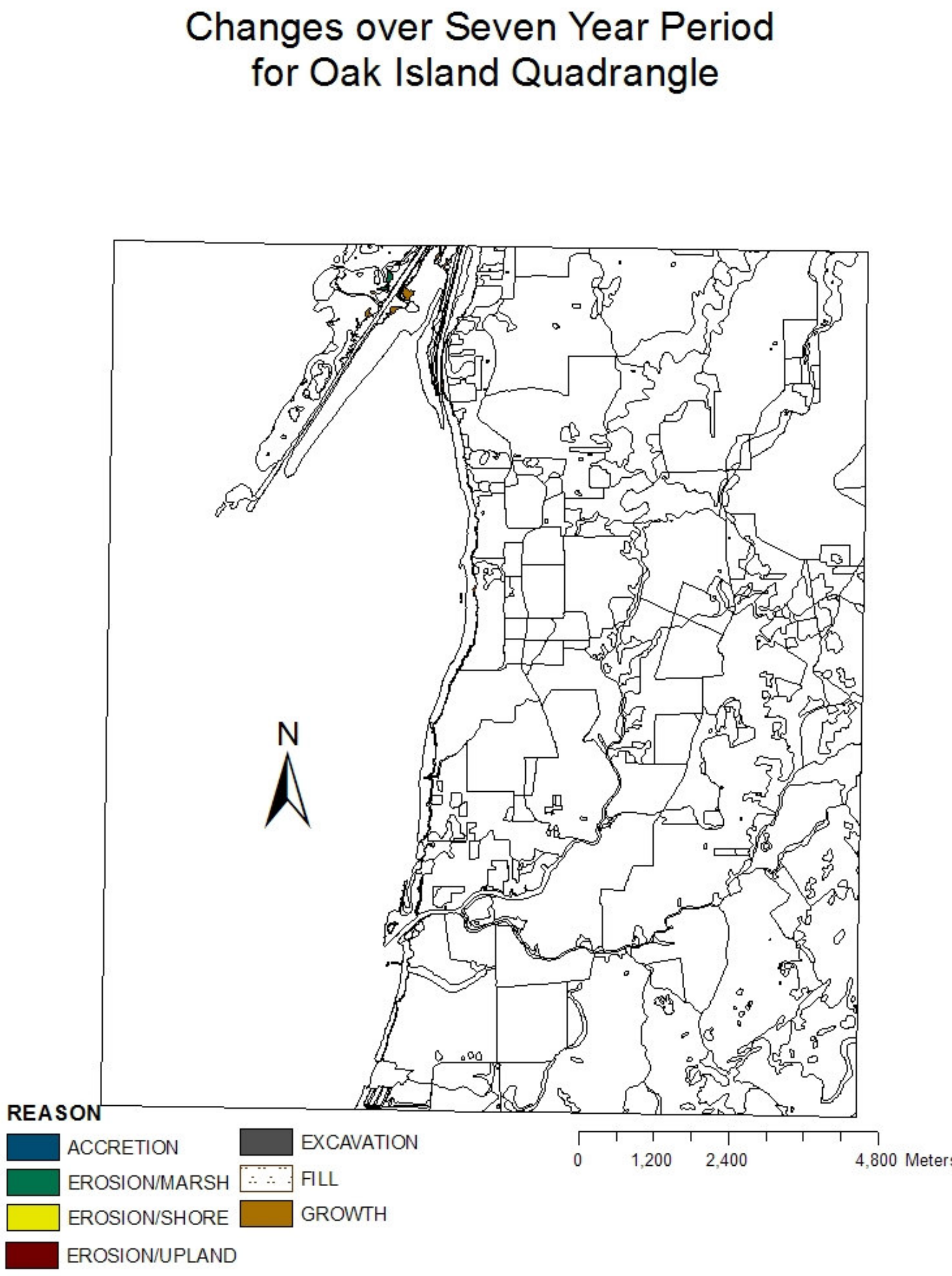
C-18: League City quad changes map



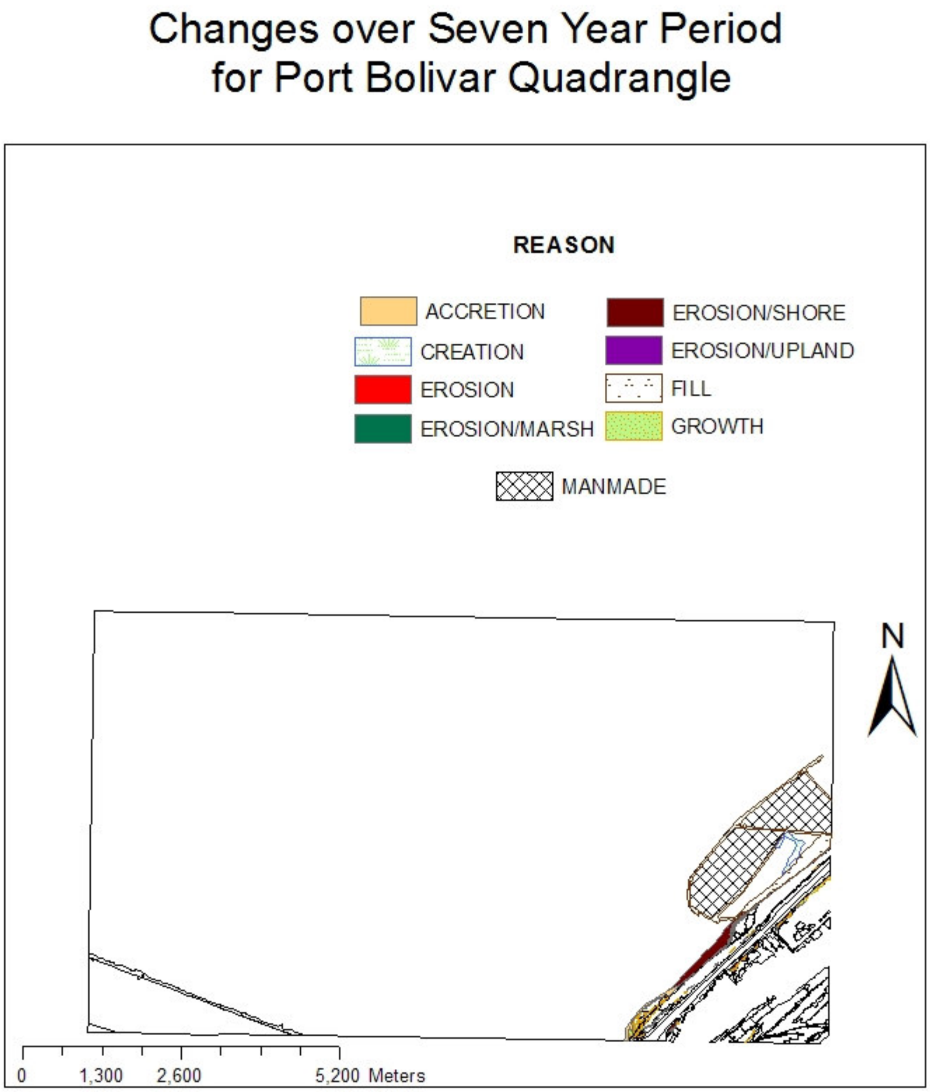
C-19: Morgans Point quad changes map



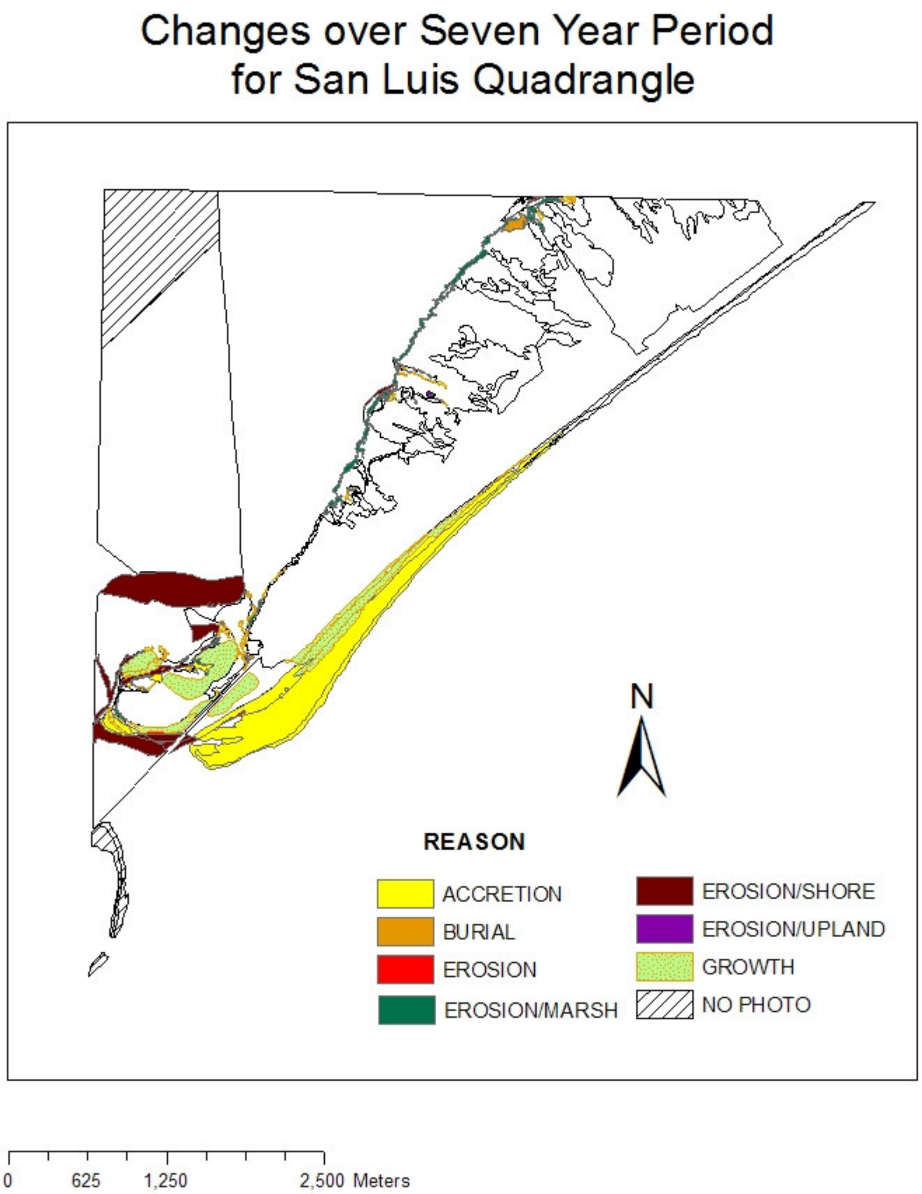
C-20: Oak Island quad changes map



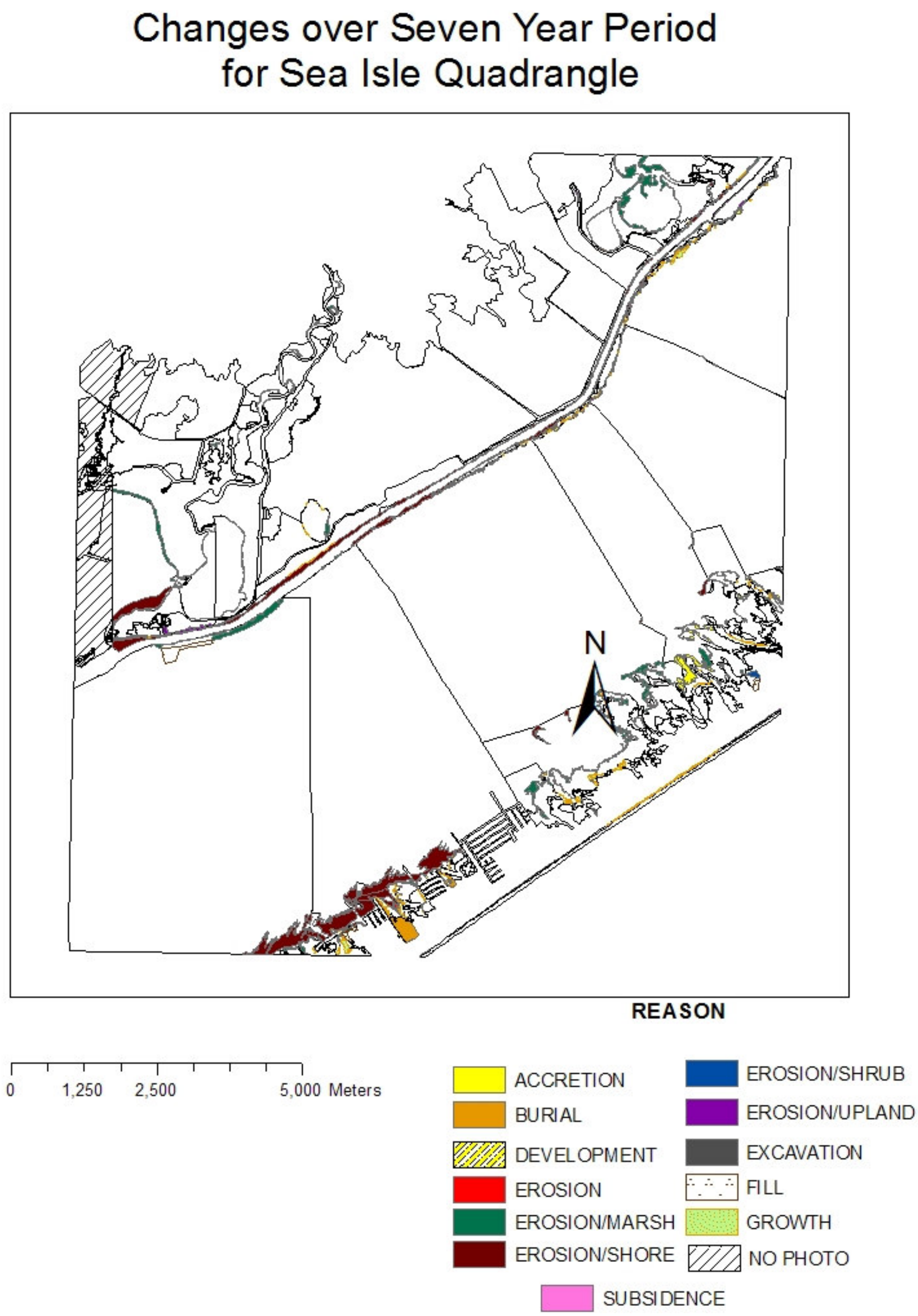
C-21: Port Bolivar quad changes map



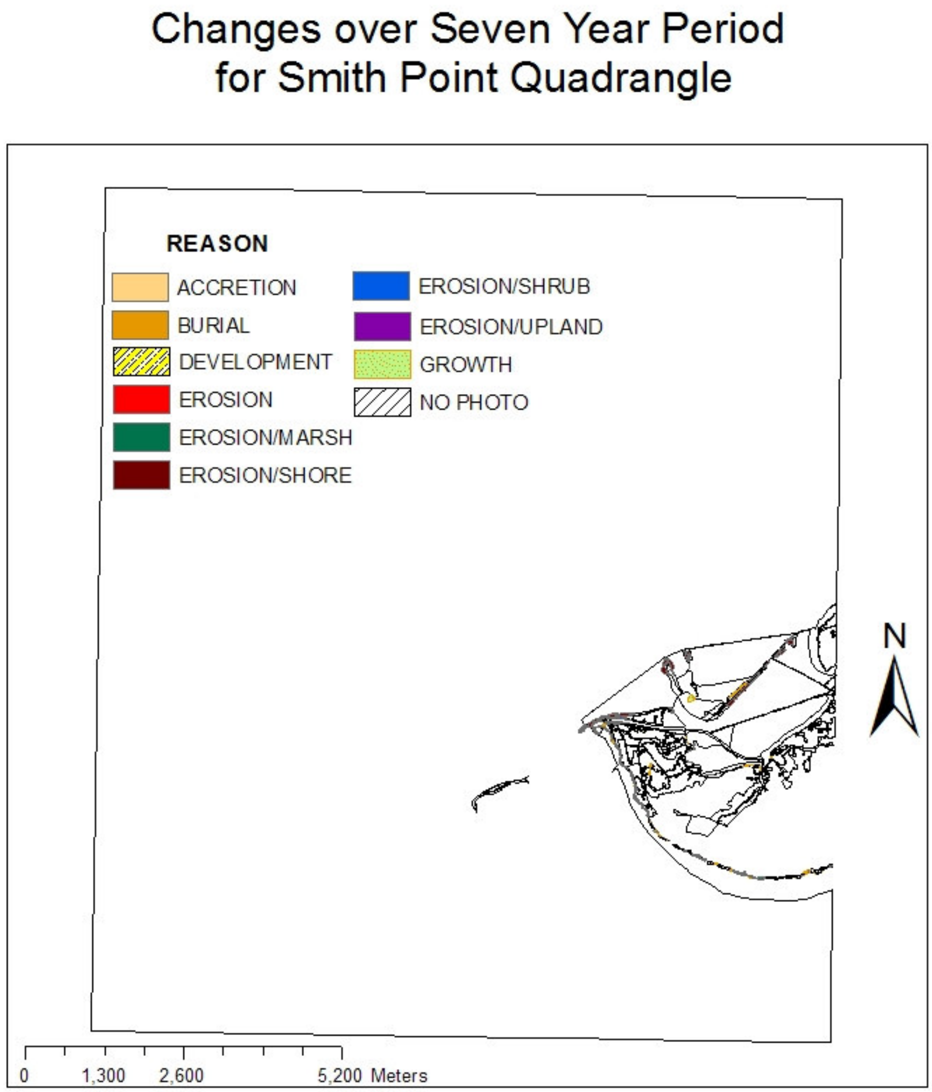
C-22: San Luis quad changes map



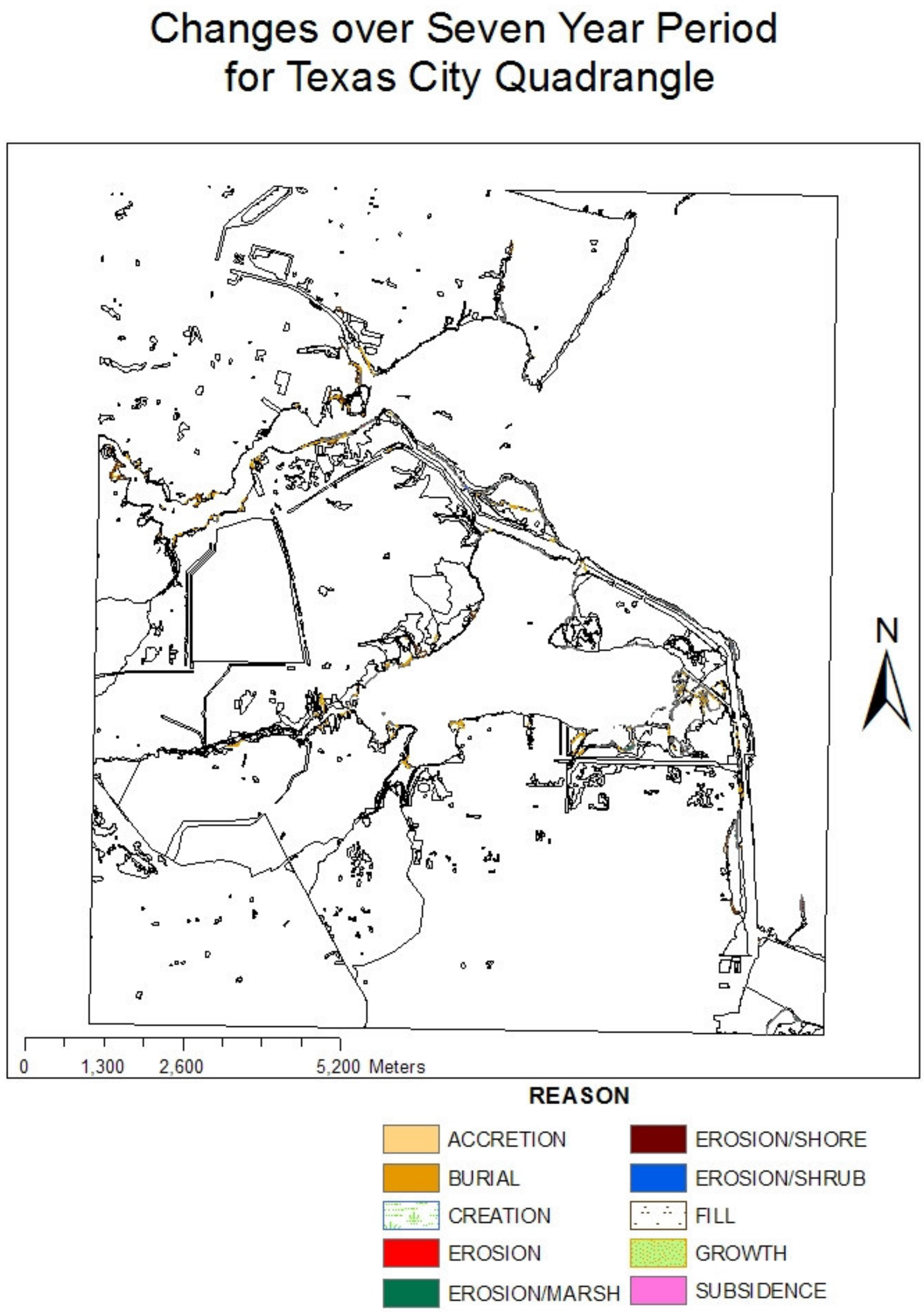
C-23: Sea Isles quad changes map



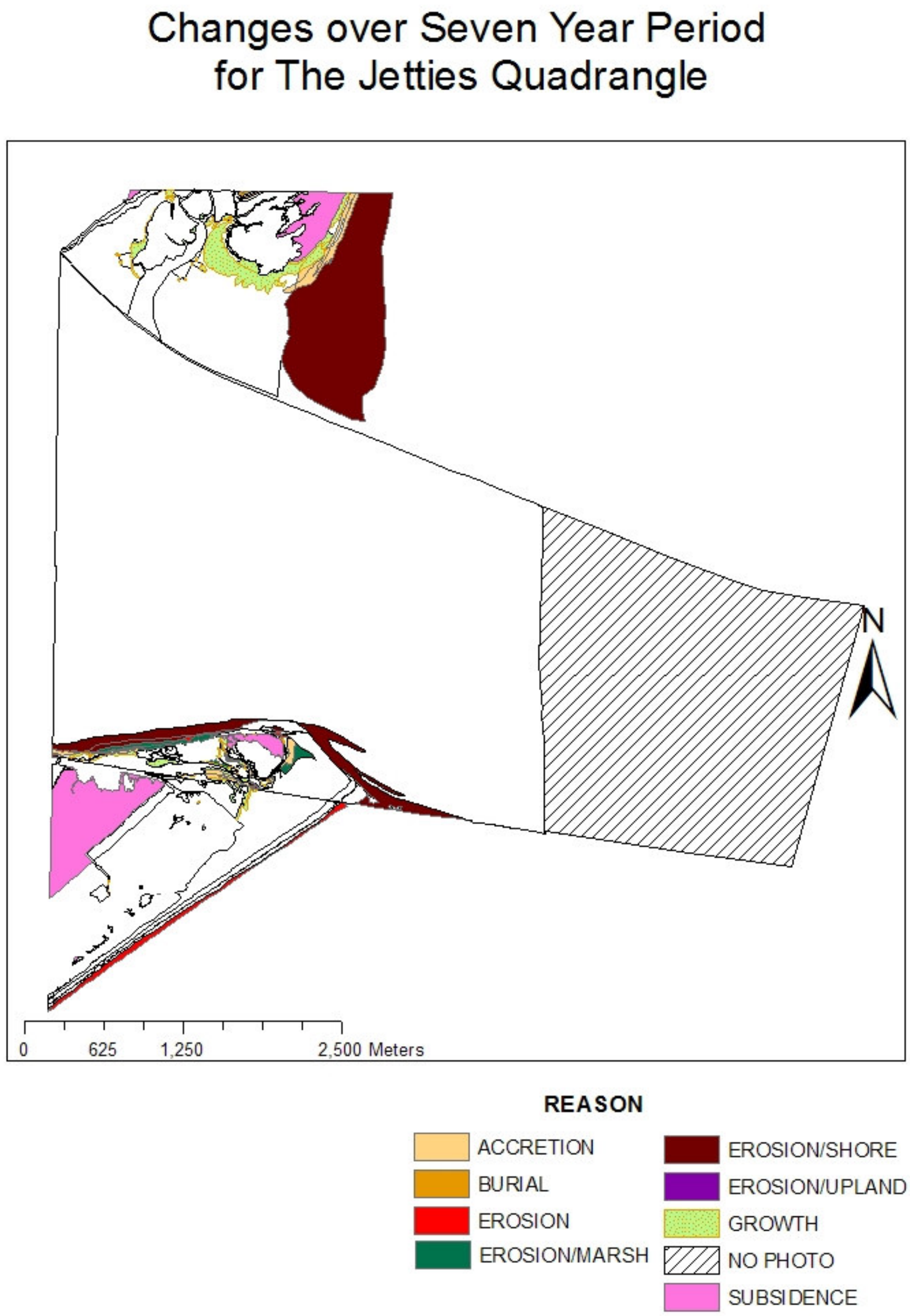
C-24: Smith Point quad changes map



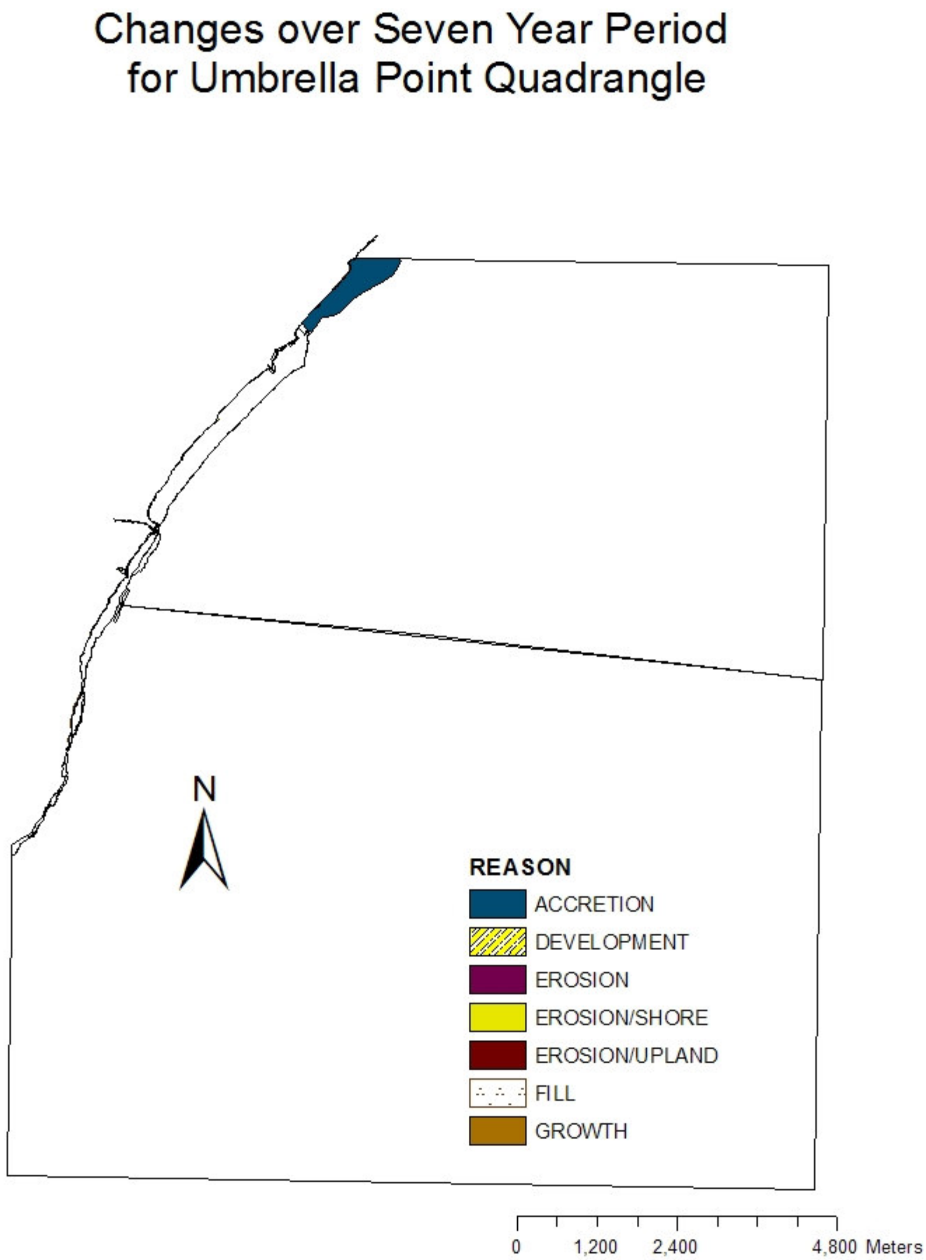
C-25: Texas City quad changes map



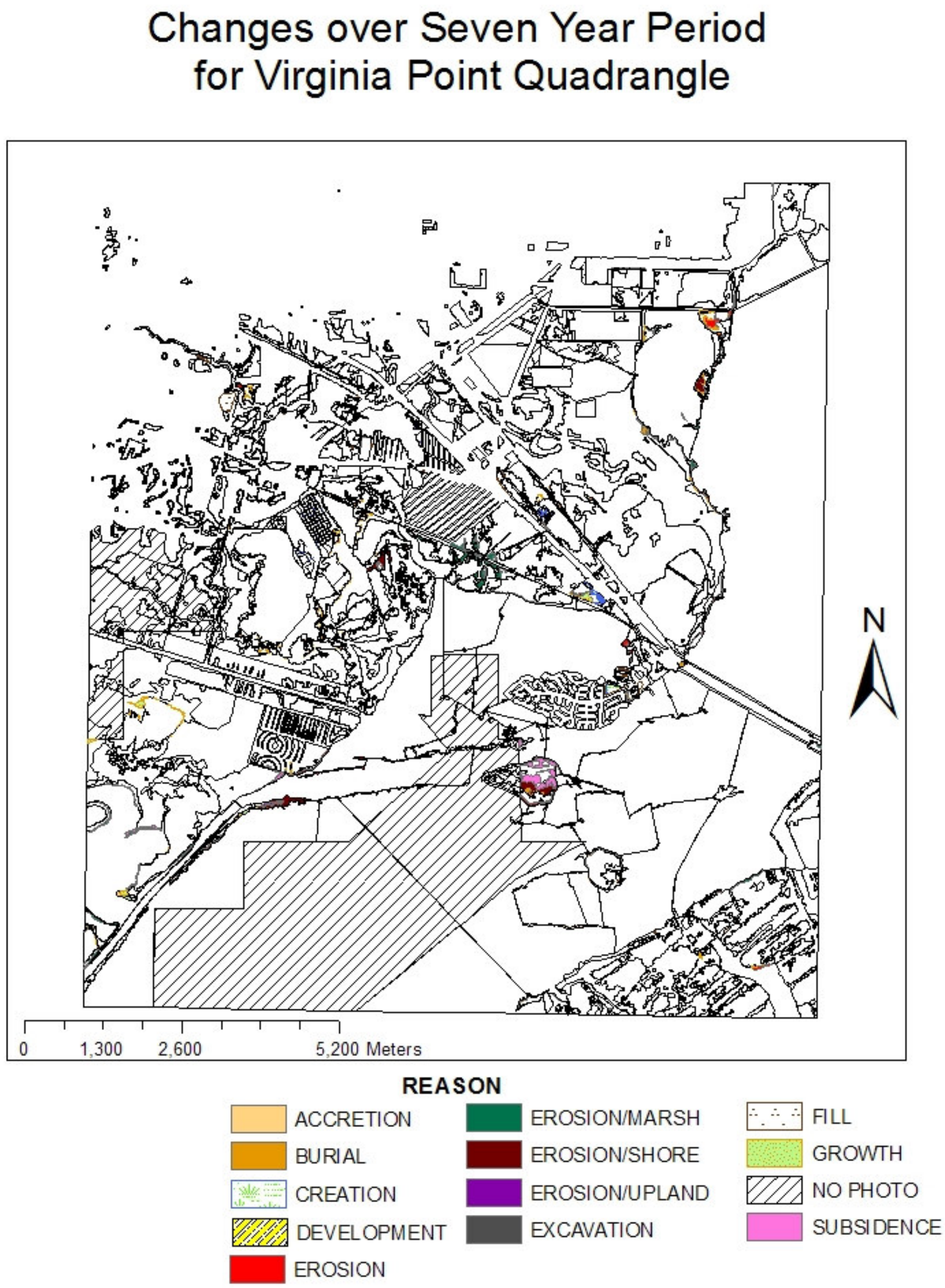
C-26: The Jetties quad changes map



C-27: Umbrella Point quad changes map



C-27: Virginia Point quad changes map



APPENDIX D

TABLES OF RAW DATA FOR ALL CATEGORIES OF HABITATS PRESENT IN THE THIRTY

QUADS IN 1995, 2002, AND CHANGES BETWEEN THOSE DATES

D-1.1: The amount of acreage divided into different estuarine and marine habitats, as classified by Cowardin system using modifiers from original NWI work, present in 1995 in the Anahuac, Bacliff, Caplen, Christmas Point, Cove, Dickinson, Flake, Frozen Point, Galveston and High Island quads circa Galveston Bay Estuary, Texas.

Habitat	Anahuac	Bacliff	Caplen	Christmas Point	Cove	Dickinson	Flake	Frozen Point	Galveston	High Island
E1AB	107.35		7.57	108.99				39.24	9.58	
E1SBL							0.57	22.45		
E1SBLx								63.24		
E1SBM	4.50									
E1UBL	73.72	39264.05	1685.78	13102.38	4146.07	170.35	15820.67	14916.37	16981.46	3035.94
E1UBLh					4.73					7.06
E1UBLhs										
E1UBLhx										
E1UBLx		25.02	157.80	517.22	42.04	4.24	518.48	246.49	1234.81	673.51
E1UBL/USM										
E1UBM				1424.00						
E2EM/SSN										
E2EM/UBN										
E2EM/UBNhs										
E2EM/UBNs				7.49						
E2EM/UBP				184.09					60.54	
E2EM/UBPs				8.11						
E2EM/USN										
E2EM/USP							0.16			
E2EM1N	2646.45	256.60	1417.12	9137.46	253.93	6.03	2423.49	8161.96	569.56	763.03
E2EM1Nhx										117.13
E2EM1Ns				1.48			242.04			
E2EM1Nx										

D1.1: continued

Habitat	Anahuac	Bacliff	Caplen	Christmas Point	Cove	Dickinson	Flake	Frozen Point	Galveston	High Island
E2EM1N/UBL									5.05	
E2EM1P	42.11	20.00	701.20	2947.81	2956.45	65.07	1163.96	7432.09	424.70	20777.19
E2EM1Ph										
E2EM1Ps			123.02	329.45						
E2EM1Psh								288.50		
E2EM1Px										8.13
E2FOP										
E2RFgeo										
E2RF2M										
E2RS									4.58	
E2RSP									0.17	
E2SBM					0.21			4.84		
E2SS1N	0.69	1.01		1.84						
E2SS1Ns				0.39						
E2SS1P		2.31		228.36	14.40		13.62	49.93	24.77	25.84
E2SS1Ps				131.82						
E2SS3P										
E2UB/EMN									0.98	
E2UB/EMP				5.62					0.96	
E2UB/SSP				8.57						
E2UBM	60.64	12.37	92.26	54.01	26.02	0.10	138.38	944.02	88.38	34.46
E2UBMh		0.36								
E2UBMhx		0.24								
E2UBMs			61.58							
E2UBMx										
E2UBN	1193.06			188.30			25.34	49.00	8.51	3.02
E2UBNhs										
E2UBNs										140.55
E2UBNx										
E2UBP	0.83		36.99	42.50			7.95	8.89	7.62	
E2UBPhs										
E2UBPs				3.33				0.53		
E2US/EMN				99.36						
E2US/EMP										
E2USM	0.53	53.45		347.01	1150.61		289.57		23.38	4.29
E2USMs							53.62			
E2USMx					3.27					

D1.1: continued

Habitat	Anahuac	Bacliff	Caplen	Christmas Point	Cove	Dickinson	Flake	Frozen Point	Galveston	High Island
E2USN	79.66	48.31	12.08	687.57	79.26	79.92	102.12	52.43	103.18	9.72
E2USNs				8.18						
E2USNx										
E2USP		7.54	11.44	26.66	11.23	1.51	29.26	6.96	26.22	2.65
E2USPs				19.19						
M1UBL				8778.48			13060.08			9528.97
M2RS									10.98	
M2USM							114.94		23.41	
M2USN			87.34	117.67			289.47		102.11	142.01
M2USP			115.35	55.96			36.80	14.05	58.09	117.83
Total	4209.55	39691.26	4509.54	38573.27	8688.22	327.22	34330.54	32301.02	19769.03	35391.33

D1.2: The amount of acreage divided into different estuarine and marine habitats, as classified by Cowardin system using modifiers from original NWI work, present in 1995 in the Highlands, Hitchcock, Hoskins Mound, Lake Como, Lake Stephenson, Laporte, League city, Morgans Point, Oak Island, Oyster Bayou, and Oyster Creek quads circa Galveston Bay Estuary, Texas.

Habitat	Highlands	Hitchcock	Hoskins Mound	Lake Como	Lake Stephenson	Laporte	League City	Morgans Point	Oak Island	Oyster Bayou	Oyster Creek
E1AB		64.73	20.47	1.79							
E1SBL											
E1SBLx										2.30	
E1SBM											
E1UBL	4711.52	587.52	7951.19	8041.80	18835.48	5622.69	4438.73	16912.59	16612.04	31.23	1640.40
E1UBLh											
E1UBLhs						336.13					
E1UBLhx											
E1UBLx	147.45	108.02	76.24	241.56	19.35	250.55	570.23	26.38	136.12		49.18
E1UBL/USM											
E1UBM										11.39	2.88
E2EM/SSN			41.35								
E2EM/UBN				26.03							
E2EM/UBNhs											
E2EM/UBNs											
E2EM/UBP											
E2EM/UBPs											
E2EM/USN	8.99										
E2EM/USP											
E2EM1N	85.51	1471.65	2108.85	1197.78	1703.80	67.00	27.30	1035.34	110.88		745.27
E2EM1Nhx											
E2EM1Ns			2.59					13.48			
E2EM1Nx											
E2EM1N/UBL											
E2EM1P	237.69	1651.89	5428.39	695.51	8031.12	145.26	302.74	199.80	168.07	651.92	7394.14
E2EM1Ph	648.28										
E2EM1Ps			3.88								
E2EM1Psh											
E2EM1Px				0.29							3.10
E2FOP								2.84			
E2RS							0.51				

D1.2: continued

Habitat	Highlands	Hitchcock	Hoskins Mound	Lake Como	Lake Stephenson	Laporte	League City	Morgans Point	Oak Island	Oyster Bayou	Oyster Creek
E2SS1N											
E2SS1Ns											
E2SS1P	44.96		68.60	46.46	1.62		34.58	111.12	20.31		6.46
E2SS1Ps	79.42			3.78							
E2SS3P											
E2UB/EMN			6.97								
E2UB/EMP											
E2UB/SSP											
E2UBM	20.76	1024.30		1.65	21.81	32.03	25.96	436.69	820.07		
E2UBMh											
E2UBMhx											
E2UBMs											
E2UBMx											
E2UBN			15.31	25.64			15.82	227.46	9.92		10.05
E2UBNhs						1441.07					
E2UBNs								135.96			
E2UBNx											
E2UBP			7.18	121.61							2.31
E2UBPhs											
E2UBPs											
E2US/EMN	1.88		1.66								
E2US/EMP			4.99								
E2USM	286.84		250.64		163.81	113.74	607.68	318.30	45.17		
E2USMh											
E2USMs											
E2USMx											
E2USN	414.13	112.48	298.52	6.46	84.69	153.20	82.78	647.15	463.34		23.33
E2USNs								25.34			
E2USNx								0.52			
E2USP	58.30	11.96	21.86	0.39	16.63	21.13		26.91	0.82		0.86
E2USPs			5.14								
M1UBL											
M2USN				146.58							
M2USP				33.98							
Total	6745.73	5032.54	16313.82	10591.33	28878.31	8182.79	6106.33	20119.88	18386.74	696.85	9877.97

D-1.3: The amount of acreage divided into different estuarine and marine habitats, as classified by Cowardin system using modifiers from original NWI work, present in 1995 in the Port Bolivar, San Luis, Sea Isle, Smith Point, Stanislind Reservoir, Texas City, The Jetties, Umbrella Point, and Virginia Point quads circa Galveston Bay Estuary, Texas.

Habitat	Port Bolivar	San Luis	Sea Isle	Smith Point	Stanislind Reservoir	Texas City	The Jetties	Umbrella Point	Virginia Point	Project Totals
E1AB		0.02	5.14					18.84		383.71
E1SBL										23.02
E1SBLx										65.54
E1SBM										4.50
E1UBL	19125.93	1805.03	20082.69	39094.81	38.30	13781.33	4381.36	36438.54	18426.32	347756.29
E1UBLh										11.79
E1UBLhs										336.13
E1UBLhx			4.73							4.73
E1UBLx	105.27		640.50	56.34	0.26	420.02	2.90		1134.52	7404.50
E1UBM			46.74		4.88					1489.90
E2EM/SSN										41.35
E2EM/UBN										26.03
E2EM/UBNhs			207.21							207.21
E2EM/UBNs										7.49
E2EM/UBP										244.63
E2EM/UBPs										8.11
E2EM/USN										8.99
E2EM/USP										0.16
E2EM1N	181.60	347.18	5597.98	369.45		476.28	174.99	1.80	2762.41	44100.70
E2EM1Nhx										117.13
E2EM1Ns			36.16						3.81	299.57
E2EM1Nx						2.65	2.81			5.46
E2EM1N/UBL										5.05
E2EM1P	118.39	501.53	2545.24	99.10	2198.27	503.87	154.99	2.15	2371.46	69932.10
E2EM1Ph										648.28
E2EM1Ps	11.24		30.02			24.88			76.68	599.16
E2EM1Psh										288.50
E2EM1Px						2.16			11.57	25.25
E2FOP										2.84
E2RF2M									6.85	6.85
E2RS									2.69	7.78
E2RSP										0.17
E2SBM										5.05
E2SS1N										3.54
E2SS1Ns										0.39

D1.3 continued

Habitat	Port Bolivar	San Luis	Sea Isle	Smith Point	Stanislind Reservoir	Texas City	The Jetties	Umbrella Point	Virginia Point	Project Totals
E2SS1P	7.93		68.67	13.68		5.51			7.83	796.96
E2SS1Ps			5.10							220.12
E2SS3P						9.76			69.00	78.76
E2UB/EMN		8.31	19.44							35.69
E2UB/EMP										6.58
E2UB/SSP										8.57
E2UBM	17.87	92.78	239.97	244.71	1.63	19.32	2.55		26.57	4479.31
E2UBMh										0.36
E2UBMhx										0.24
E2UBMs										61.58
E2UBMx	4.79									4.79
E2UBN	0.50	29.16	59.30	19.70			3.47			1883.56
E2UBNhs										1441.07
E2UBNs										276.52
E2UBNx										0.00
E2UBP	15.80	7.57	75.87				16.14		50.47	401.73
E2UBPhs										0.00
E2UBPs			3.57							7.43
E2US/EMN										102.90
E2US/EMP										4.99
E2USM	116.47	123.01		0.53		197.73		369.59	25.12	4487.47
E2USMs										53.62
E2USMx										3.27
E2USN	55.06	6.84	72.90	80.68		151.93	81.32	15.60	198.28	4202.94
E2USNs			122.08			2.98			21.13	179.71
E2USNx						9.97			5.48	15.97
E2USP	26.37	14.96	4.62	50.60		2.44	57.63		82.65	521.61
E2USPs			2.81						21.52	48.66
M1UBL		151.35								31518.88
M2RS										10.98
M2USM		4.88					255.53			398.75
M2USN		98.89	101.09				62.02			1147.20
M2USP		74.71	35.61				88.93			631.32
Total	19787.22	3266.22	30007.44	40029.58	2243.33	15610.84	5284.65	36846.51	25304.36	527103.45

D-2.1: Amount in acres of estuarine and marine habitats, classified according to the Cowardin system including modifiers used in the original NWI files, present in 2002 in the Anahuac, Bacliff, Caplen, Christmas Point, Cove, Dickinson, Flake, Frozen Point, Galveston, and High Island circa Galveston Bay Estuary, Texas.

Habitat	Anahuac	Bacliff	Caplen	Christmas Point	Cove	Dickinson	Flake	Frozen Point	Galveston	High Island
E1AB	106.59		7.57	96.69				39.24		
E1SBL							0.57	22.45		
E1SBLx								63.24		
E1SBM	4.50									
E1UBL	17.20	39266.72	1658.83	13710.75	4164.1	180.33	15868.2	14952.38	17225.515	2948.6968
E1UBLh					4.73		24.77			7.0587417
E1UBLhs										
E1UBLhx										
E1UBLx		25.02	155.15	517.22	38.97	4.24	528.49	245.03	1245.6575	667.96925
E1UBL/USM					1.49					
E1UBM				1416.56						
E2EM/SSN										
E2EM/UBN										
E2EM/UBNhs										
E2EM/UBNs				7.49						
E2EM/UBP				184.09					60.929126	
E2EM/UBPs				8.11						
E2EM/USN										
E2EM/USP										
E2EM1N	2673.75	257.80	1421.44	9111.37	260.44	5.90	2379.02	8122.01	480.96399	813.76944
E2EM1Nhx										117.12855
E2EM1Ns				1.35			215.47			
E2EM1Nx										
E2EM1N/UBL									5.0488529	
E2EM1P	41.98	20.35	694.09	2946.92	2926.8	65.34	1130.36	7398.82	465.14859	20772.281
E2EM1Ph										
E2EM1Ps			120.33	329.45						
E2EM1Psh								288.34		
E2EM1Px										1.1443312
E2RS		2.593163							6.3020883	
E2RSP									0.1665606	
E2SBM					0.2051			4.840651259		
E2SS1N	0.689285			1.835937883						

D2.1: continued

Habitat	Anahuac	Bacliff	Caplen	Christmas Point	Cove	Dickinson	Flake	Frozen Point	Galveston	High Island
E2SS1Ns				0.385877712						
E2SS1P		0.312623		228.3592111	14.691		13.6227	49.92985153	21.770412	25.866319
E2SS1Ps				128.2592331						
E2SS3P										
E2UB/EMN									0.9751203	
E2UB/EMP				5.616351725					0.8331359	
E2UB/SSP				8.569472229						
E2UBM	58.79906	12.40452	91.10174	61.51936205	25.944	19.34448	138.381	942.4527832	5.72594	20.598526
E2UBMh		0.358867								
E2UBMhx		0.24427								
E2UBMs			61.58055							
E2UBMx										
E2UBN	1093.938			78.56909618			24.5355	48.24057734	1.0852356	2.9669111
E2UBNhs										
E2UBNs										140.55255
E2UBNx						0.576515				
E2UBP			36.98641	42.50420913			7.95267	18.14677513	5.898254	
E2UBPhs										
E2UBPs				3.326087738				0.532303631		
E2US/EMN				99.36217292						
E2US/EMP									1.6047201	
E2USM	0.6588	59.24918		319.1219755	1153.6		255.292		0.3529491	63.231893
E2USMh										
E2USMs							42.8679			
E2USMx					3.1605					
E2USN	211.4338	46.0902	52.24382	262.0119299	82.83	50.62567	137.72	70.36224931	19.968641	18.365014
E2USNs				8.184407642						
E2USNx										
E2USP		6.787763	7.589804	25.39044454	11.037	0.805919	25.5337	5.830086783	27.741543	2.5890972
E2USPs				19.1917042			18.4639			
M1UBL				8778.478718			13119.4		21.465858	9528.6254
M2RS									11.633748	
M2USM									40.05441	
M2USN			87.34393	117.6724445			317.296		46.953008	142.09444
M2USP			115.3515	55.95558679			36.8047	14.05309677	68.120186	118.08687
Total	4209.546	39697.94	4509.599	38574.32513	8688	327.163	34284.7	32285.90044	19763.915	35391.025

D-2.2: Amount in acres of estuarine and marine habitats, classified according to the Cowardin system including modifiers used in the original NWI files, present in 2002 in the Highlands, Hitchcock, Hoskins Mound, Lake Como, Lake Stephenson, Laporte, League City, Morgans Point, Oak Island, Oyster Bayou, and Oyster Creek circa Galveston Bay Estuary, Texas.

Habitat	Highlands	Hitchcock	Hoskins Mound	Lake Como	Lake Stephenson	Laporte	League City	Morgans Point	Oak Island	Oyster Bayou	Oyster Creek
E1AB		64.727535	20.46531187	11.412267	4.64646101						
E1SBL											
E1SBLx										2.30	
E1SBM											
E1UBL	4716.6907	587.62117	8070.195864	8018.559	18855.24532	5634.4495	4454.31	16325.56	16613.63	31.23	1640.40
E1UBLh											
E1UBLhs						322.49747					
E1UBLhx											
E1UBLx	147.56907	113.03996	76.23767228	254.54559	19.11379364	248.05775	572.99	26.38	135.60		49.18
E1UBL/USM											
E1UBM			52.51578453							11.39	2.88
E2EM/SSN			41.35206868								
E2EM/UBN				26.033744							
E2EM/UBNhs											
E2EM/UBNs											
E2EM/UBP											
E2EM/UBPs											
E2EM/USN	8.9861717						0.07				
E2EM/USP											
E2EM1N	90.279701	1469.9092	2099.595651	1153.9621	1708.71812	108.08958	50.71	1035.94	107.15		745.27
E2EM1Nhx											
E2EM1Ns			2.594876169								
E2EM1Nx											
E2EM1P	229.78897	1635.211	5428.295536	692.54915	8047.050021	145.25574	294.39	194.17	189.45	651.92	7394.14
E2EM1Ps			3.720297862								
E2EM1Px				0.2859793							3.10
E2FOP								2.84			
E2RFgeo				5.2523137							
E2RF2M							0.49				
E2RS					0.838780999	0.1320359	1.87				
E2RSP						0.1068058					

D2.2: continued

Habitat	Highlands	Hitchcock	Hoskins Mound	Lake Como	Lake Stephenson	Laporte	League City	Morgans Point	Oak Island	Oyster Bayou	Oyster Creek
E2SS1N											
E2SS1Ns											
E2SS1P	45.441111		68.59786366	32.909297	1.235027194		30.64	107.82	20.31		6.46
E2SS1Ps	79.42271			3.7824352							
E2SS3P											
E2UB/EMN			6.968079818								
E2UB/EMP											
E2UB/SSP											
E2UBM	30.70407	1026.9196		1.6559292	19.20724051	32.030335	15.98	545.74	799.61		
E2UBMh											
E2UBMhx											
E2UBMs											
E2UBMx											
E2UBN			15.31213659	26.778743			0.49	226.62	9.92		10.05
E2UBNhs						1426.572		759.60			
E2UBNs								154.88			
E2UBNx											
E2UBP			7.17983517	120.8193				0.81			2.31
E2UBPhs	648.27692										
E2UBPs											
E2US/EMN	1.8783176		1.661041558								
E2US/EMP			4.989979256								
E2USM	281.27381		158.3151111	0.5493856	163.8091169	103.76311	629.73	190.33	45.17		
E2USMh											
E2USMs											
E2USMx											
E2USN	393.96193	108.09512	232.5327119	44.060227	62.38544297	153.63745	61.97	499.48	477.05		23.33
E2USNs							1.93				
E2USNx								0.52			
E2USP	58.302751	11.957868	21.8582902	0.3904488	19.83763045	20.801333	1.32	25.77	0.20		0.86
E2USPs			2.218371957								
M1UBL											
M2USM											
M2USN				146.58369							
M2USP				33.98115							
Total	6732.5762	5017.4814	16314.60648	10574.111	28902.08695	8195.3931	6116.89	20096.46	18398.10	696.85	9877.97

D2.3**:** Amount in acres of estuarine and marine habitats, classified according to the Cowardin system including modifiers used in the original NWI files, present in 2002 in the Port Bolivar, San Luis, Sea Isle, Smith Point, Stanislind Reservoir, Texas City, The Jetties, Umbrella Point, and Virginia Point circa Galveston Bay Estuary, Texas.

Habitat	Port Bolivar	San Luis	Sea Isle	Smith Point	Stanislind Reservoir	Texas City	The Jetties	Umbrella Point	Virginia Point	Project Total
E1AB			3.21					0.27		354.83
E1SBL										23.02
E1SBLx										65.54
E1SBM										4.50
E1UBL	18564.84	1907.67	20679.53	39134.59	38.30	13813.17	4391.19	36323.89	18592.42	348386.19
E1UBLh	516.51									553.08
E1UBLhs										322.50
E1UBLhx			4.73							4.73
E1UBLx	105.27		641.22	55.25	0.26	419.59	2.75		1125.32	7420.12
E1UBL/USM										1.49
E1UBM			6.45		4.88					1494.68
E2EM/SSN										41.35
E2EM/UBN										26.03
E2EM/UBNhs			205.15							205.15
E2EM/UBNs										7.49
E2EM/UBP										245.02
E2EM/UBPs										8.11
E2EM/USN										9.05
E2EM1N	212.96	311.57	5356.91	363.13		463.67	313.39	3.41	2786.53	43907.65
E2EM1Nhx										117.13
E2EM1Ns			21.09						3.49	243.99
E2EM1Nx						2.65	2.81			5.46
E2EM1N/UBL										5.05
E2EM1P	119.25	535.30	2560.84	97.08	2198.27	476.14	97.96	0.17	2276.72	69726.03
E2EM1Ps	11.24		27.15			22.77			71.18	585.84
E2EM1Psh										288.34
E2EM1Px						2.16			11.57	18.26
E2FOP										2.84
E2RFgeo										5.25
E2RF2M									3.21	3.69
E2RS								0.16	2.62	14.51
E2RSP										0.27
E2SBM										5.05

D2.3: continued

Habitat	Port Bolivar	San Luis	Sea Isle	Smith Point	Stanislind Reservoir	Texas City	The Jetties	Umbrella Point	Virginia Point	Project Total
E2SS1N										2.53
E2SS1Ns										0.39
E2SS1P	7.93		64.54	9.61		3.99	1.26	0.23	9.01	764.54
E2SS1Ps			4.67							216.14
E2SS3P						9.76			69.00	78.76
E2UB/EMN			19.44							27.38
E2UB/EMP										6.45
E2UB/SSP										8.57
E2UBM	20.75	13.43	23.52	239.81	1.63	18.76	4.01		28.47	4198.50
E2UBMh										0.36
E2UBMhx										0.24
E2UBMs										61.58
E2UBMx	4.79									4.79
E2UBN	0.50	22.63	42.35	14.81			3.89		3.21	1625.89
E2UBNhs										2186.17
E2UBNs										295.44
E2UBNx										0.58
E2UBP	15.80	4.70	71.20				11.76		21.34	367.41
E2UBPhs										648.28
E2UBPs			1.20							5.05
E2US/EMN										102.90
E2US/EMP										6.59
E2USM	2.25	103.55	3.57			195.34		499.64	39.64	4268.44
E2USMh	67.42									67.42
E2USMs										42.87
E2USMx										3.16
E2USN	39.42	28.84	100.45	71.68		147.88	34.23	10.40	166.71	3607.76
E2USNs			39.06			2.98				52.16
E2USNx						9.35				9.86
E2USP	32.96	9.70	17.60	39.70		89.92	53.56		65.36	583.40
E2USPs			1.89						3.21	44.98
M1UBL		2.44					238.85			31689.21
M2RS										11.63
M2USM		5.69					18.18			63.92
M2USN		71.51	101.09				51.80			1082.35
M2USP		196.41	34.26				88.71			761.74
Total	19721.89	3213.45	30031.15	40025.66	2243.33	15678.12	5314.34	36838.17	25279.00	526999.72

D-3.1: Amount of change in acres for each habitat type per quad(Anahuac-Highlands) from 1995 to 2002 in the Galveston Bay Estuary, Texas.

Habitat	Anahuac	Bacliff	Caplen	Christmas Point	Cove	Dickinson	Flake	Frozen Point	Galveston	High Island	Highlands
E1AB	-0.76	0.00	0.00	-12.30	0.00	0.00	0.00	0.00	-9.58	0.00	0.00
E1SBL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E1SBLx	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E1SBM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E1UBL	-56.52	2.68	-26.96	608.38	18.01	9.98	47.52	36.00	244.06	-87.24	5.17
E1UBLh	0.00	0.00	0.00	0.00	0.00	0.00	24.77	0.00	0.00	0.00	0.00
E1UBLhs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E1UBLhx	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E1UBLx	0.00	0.00	-2.65	0.00	-3.07	0.00	10.00	-1.46	10.85	-5.54	0.12
E1UBL/USM	0.00	0.00	0.00	0.00	1.49	0.00	0.00	0.00	0.00	0.00	0.00
E1UBM	0.00	0.00	0.00	-7.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2EM/SSN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2EM/UBN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2EM/UBNhs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2EM/UBNs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2EM/UBP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.39	0.00	0.00
E2EM/UBPs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2EM/USN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2EM/USP	0.00	0.00	0.00	0.00	0.00	0.00	-0.16	0.00	0.00	0.00	0.00
E2EM1N	27.30	1.20	4.32	-26.09	6.51	-0.13	-44.48	-39.96	-88.59	50.74	4.77
E2EM1Nhx	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2EM1Ns	0.00	0.00	0.00	-0.13	0.00	0.00	-26.57	0.00	0.00	0.00	0.00
E2EM1Nx	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2EM1N/UBL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2EM1P	-0.13	0.35	-7.12	-0.89	-29.66	0.27	-33.60	-33.27	40.45	-4.91	-7.90
E2EM1Ph	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-648.28
E2EM1Ps	0.00	0.00	-2.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2EM1Psh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.16	0.00	0.00	0.00
E2EM1Px	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-6.99	0.00
E2FOP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2RF2M	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2RS	0.00	2.59	0.00	0.00	0.00	0.00	0.00	0.00	1.72	0.00	0.00
E2RSP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2SS1P	0.00	-2.00	0.00	0.00	0.29	0.00	0.00	0.00	-3.00	0.02	0.48

D3.1: continued

Habitat	Anahuac	Bacliff	Caplen	Christmas Point	Cove	Dickinson	Flake	Frozen Point	Galveston	High Island	Highlands
E2SS1Ps	0.00	0.00	0.00	-3.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2SS3P	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2UB/EMN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2UB/EMP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.13	0.00	0.00
E2UB/SSP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2UBM	-1.84	0.03	-1.16	7.51	-0.07	19.25	0.00	-1.57	-82.65	-13.86	9.95
E2UBMh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2UBMhx	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2UBMs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2UBMx	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2UBN	-99.12	0.00	0.00	-109.73	0.00	0.00	-0.80	-0.76	-7.42	-0.05	0.00
E2UBNhs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2UBNs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2UBNx	0.00	0.00	0.00	0.00	0.00	0.58	0.00	0.00	0.00	0.00	0.00
E2UBP	-0.83	0.00	0.00	0.00	0.00	0.00	0.00	9.25	-1.73	0.00	0.00
E2UBPhs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	648.28
E2UBPs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2US/EMN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2US/EMP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.60	0.00	0.00
E2USM	0.13	5.80	0.00	-27.88	2.99	0.00	-34.28	0.00	-23.02	58.94	-5.57
E2USMh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2USMs	0.00	0.00	0.00	0.00	0.00	0.00	-10.76	0.00	0.00	0.00	0.00
E2USMx	0.00	0.00	0.00	0.00	-0.11	0.00	0.00	0.00	0.00	0.00	0.00
E2USN	131.77	-2.22	40.17	-425.56	3.57	-29.29	35.60	17.93	-83.21	8.65	-20.17
E2USNs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2USNx	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2USP	0.00	-0.75	-3.85	-1.27	-0.19	-0.71	-3.73	-1.13	1.52	-0.06	0.00
E2USPs	0.00	0.00	0.00	0.00	0.00	0.00	18.46	0.00	0.00	0.00	0.00
M1UBL	0.00	0.00	0.00	0.00	0.00	0.00	59.27	0.00	21.47	-0.34	0.00
M2RS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.66	0.00	0.00
M2USM	0.00	0.00	0.00	0.00	0.00	0.00	-114.94	0.00	16.64	0.00	0.00
M2USN	0.00	0.00	0.00	0.00	0.00	0.00	27.82	0.00	-55.16	0.09	0.00
M2USP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.03	0.26	0.00
Total	0.00	6.68	0.06	1.05	-0.25	-0.06	-45.85	-15.11	-5.12	-0.30	-13.16

D3.2: Amount of change in acres occurring in each habitat type per quad (Hitchcock – Oyster Creek) from 1995 to 2002 in the Galveston Bay Estuary, Texas

Habitat	Hitchcock	Hoskins Mound	Lake Como	Lake Stephenson	Laporte	League City	Morgans Point	Oak Island	Oyster Bayou	Oyster Creek
E1AB	0.00	0.00	9.62	4.65	0.00	0.00	0.00	0.00	0.00	0.00
E1SBL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E1SBLx	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E1SBM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E1UBL	0.10	119.00	-23.24	19.77	11.76	15.59	-587.03	1.60	0.00	0.00
E1UBLh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E1UBLhs	0.00	0.00	0.00	0.00	-13.63	0.00	0.00	0.00	0.00	0.00
E1UBLhx	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E1UBLx	5.02	0.00	12.98	-0.23	-2.49	2.76	0.00	-0.52	0.00	0.00
E1UBL/USM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E1UBM	0.00	52.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2EM/SSN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2EM/UBN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2EM/UBNhs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2EM/UBNs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2EM/UBP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2EM/UBPs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2EM/USN	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00
E2EM/USP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2EM1N	-1.74	-9.25	-43.82	4.92	41.09	23.42	0.60	-3.73	0.00	0.00
E2EM1Nhx	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2EM1Ns	0.00	0.00	0.00	0.00	0.00	0.00	-13.48	0.00	0.00	0.00
E2EM1Nx	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2EM1N/UBL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2EM1P	-16.67	-0.10	-2.96	15.93	0.00	-8.36	-5.63	21.38	0.00	0.00
E2EM1Ph	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2EM1Ps	0.00	-0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2EM1Psh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2EM1Px	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2FOP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2Rfgeo	0.00	0.00	5.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2RF2M	0.00	0.00	0.00	0.00	0.00	0.49	0.00	0.00	0.00	0.00
E2RS	0.00	0.00	0.00	0.84	0.13	1.36	0.00	0.00	0.00	0.00
E2RSP	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00

D3.2: continued

Habitat	Hitchcock	Hoskins Mound	Lake Como	Lake Stephenson	Laporte	League City	Morgans Point	Oak Island	Oyster Bayou	Oyster Creek
E2SS1Ps	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2SS3P	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2UB/EMN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2UB/EMP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2UB/SSP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2UBM	2.62	0.00	0.01	-2.60	0.00	-9.97	109.06	-20.46	0.00	0.00
E2UBMh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2UBMhx	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2UBMs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2UBMx	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2UBN	0.00	0.00	1.13	0.00	0.00	-15.33	-0.84	0.00	0.00	0.00
E2UBNhs	0.00	0.00	0.00	0.00	-14.50	0.00	759.60	0.00	0.00	0.00
E2UBNs	0.00	0.00	0.00	0.00	0.00	0.00	18.92	0.00	0.00	0.00
E2UBNx	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2UBP	0.00	0.00	-0.79	0.00	0.00	0.00	0.81	0.00	0.00	0.00
E2UBPhs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2UBPs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2US/EMN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2US/EMP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2USM	0.00	-92.33	0.55	0.00	-9.97	22.05	-127.97	0.00	0.00	0.00
E2USMh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2USMs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2USMx	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2USN	-4.39	-65.98	37.60	-22.31	0.43	-20.82	-147.67	13.71	0.00	0.00
E2USNs	0.00	0.00	0.00	0.00	0.00	1.93	-25.34	0.00	0.00	0.00
E2USNx	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2USP	0.00	0.00	0.00	3.21	-0.33	1.32	-1.14	-0.62	0.00	0.00
E2USPs	0.00	-2.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M1UBL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M2RS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M2USM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M2USN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M2USP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	-15.06	0.78	-17.22	23.78	12.60	10.56	-23.42	11.35	0.00	0.00

D3.3: Amount of change in acres occurring in each habitat type per quad (Port Bolivar – Virginia Point) from 1995 to 2002 in the Galveston Bay Estuary, Texas

Habitat	Port Bolivar	San Luis	Sea Isle	Smith Point	Stanislind Reservoir	Texas City	The Jetties	Umbrella Point	Virginia Point	Project Total
E1AB	0.00	-0.02	-1.92	0.00	0.00	0.00	0.00	-18.57	0.00	-28.89
E1SBL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E1SBLx	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E1SBM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E1UBL	-561.09	102.64	596.84	39.78	0.00	31.83	9.83	-114.64	166.09	629.90
E1UBLh	516.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	541.29
E1UBLhs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-13.63
E1UBLhx	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E1UBLx	0.00	0.00	0.72	-1.09	0.00	-0.43	-0.15	0.00	-9.19	15.62
E1UBL/USM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.49
E1UBM	0.00	0.00	-40.30	0.00	0.00	0.00	0.00	0.00	0.00	4.78
E2EM/SSN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2EM/UBN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2EM/UBNhs	0.00	0.00	-2.06	0.00	0.00	0.00	0.00	0.00	0.00	-2.06
E2EM/UBNs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2EM/UBP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.39
E2EM/UBPs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2EM/USN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07
E2EM/USP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.16
E2EM1N	31.35	-35.61	-241.07	-6.31	0.00	-12.61	138.40	1.61	24.11	-193.05
E2EM1Nhx	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2EM1Ns	0.00	0.00	-15.07	0.00	0.00	0.00	0.00	0.00	-0.33	-55.58
E2EM1Nx	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2EM1P	0.86	33.77	15.60	-2.02	0.00	-27.73	-57.04	-1.98	-94.74	-206.07
E2EM1Ph	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-648.28
E2EM1Ps	0.00	0.00	-2.87	0.00	0.00	-2.11	0.00	0.00	-5.50	-13.32
E2EM1Psh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.16
E2EM1Px	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-6.99
E2RFgeo	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.25
E2RF2M	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-3.64	-3.16
E2RS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	-0.07	6.73
E2RSP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11
E2SS1N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-1.01

D3.3: continued

Habitat	Port Bolivar	San Luis	Sea Isle	Smith Point	Stanislind Reservoir	Texas City	The Jetties	Umbrella Point	Virginia Point	Project Total
E2SS1Ns	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2SS1P	0.00	0.00	-4.14	-4.07	0.00	-1.52	1.26	0.23	1.19	-32.42
E2SS1Ps	0.00	0.00	-0.42	0.00	0.00	0.00	0.00	0.00	0.00	-3.98
E2SS3P	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2UB/EMN	0.00	-8.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-8.31
E2UB/EMP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.13
E2UB/SSP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2UBM	2.88	-79.35	-216.44	-4.90	0.00	-0.56	1.46	0.00	1.90	-280.80
E2UBMh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2UBMhx	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2UBMs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2UBMx	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2UBN	0.00	-6.53	-16.95	-4.89	0.00	0.00	0.41	0.00	3.21	-257.67
E2UBNhs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	745.10
E2UBNs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	18.92
E2UBNx	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.58
E2UBP	0.00	-2.87	-4.67	0.00	0.00	0.00	-4.38	0.00	-29.12	-34.32
E2UBPhs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	648.28
E2UBPs	0.00	0.00	-2.37	0.00	0.00	0.00	0.00	0.00	0.00	-2.37
E2US/EMN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E2US/EMP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.60
E2USM	-114.22	-19.46	3.57	-0.53	0.00	-2.40	0.00	130.05	14.52	-219.03
E2USMh	67.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	67.42
E2USMs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-10.76
E2USMx	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.11
E2USN	-15.64	22.00	27.55	-9.00	0.00	-4.05	-47.09	-5.20	-31.57	-595.18
E2USNs	0.00	0.00	-83.02	0.00	0.00	0.00	0.00	0.00	-21.13	-127.56
E2USNx	0.00	0.00	0.00	0.00	0.00	-0.63	0.00	0.00	-5.48	-6.11
E2USP	6.59	-5.26	12.98	-10.90	0.00	87.48	-4.08	0.00	-17.29	61.80
E2USPs	0.00	0.00	-0.91	0.00	0.00	0.00	0.00	0.00	-18.31	-3.68
M1UBL	0.00	-148.91	0.00	0.00	0.00	0.00	238.85	0.00	0.00	170.34
M2RS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.66
M2USM	0.00	0.81	0.00	0.00	0.00	0.00	-237.35	0.00	0.00	-334.83
M2USN	0.00	-27.38	0.00	0.00	0.00	0.00	-10.22	0.00	0.00	-64.84
M2USP	0.00	121.70	-1.35	0.00	0.00	0.00	-0.22	0.00	0.00	130.42
Total	-65.33	-52.77	23.71	-3.93	0.00	67.27	29.69	-8.34	-25.36	-103.73

APPENDIX E

TABLES AND RAW DATA FROM T-TEST AND MANOVA ANALYSIS OF RESULTS

E-1: Results from paired t-test comparing years for SAV, low marsh, high marsh, shrubs/trees, and shores/flats.

t-Test: Paired Two Sample for Means

Low marsh			High Marsh		
	1995	*2002*		*1995*	*2002*
Mean	1494.1	1485.6	Mean	2391.5	2362.4
Variance	5375625	5253489	Variance	17742661	1780991 8
Observations	30	30	Observations	30	30
Pearson Correlation	0.99971		Pearson Correlation	0.999588	
Hypothesized Mean Difference	0		Hypothesized Mean Difference	0	
Df	29		Df	29	
t Stat	0.751306		t Stat	1.316369	
P(T<=t) two-tail	0.458523		P(T<=t) two-tail	0.19836	
t Critical two-tail	2.045231		t Critical two-tail	2.045231	

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t-Test: Paired Two Sample for Means
Shrubs/Trees

	1995	2002
Mean	36.8	36.5
Variance	4970.9	4888.7
Observations	30	30
Pearson Correlation	0.999268	
Hypothesized Mean Difference	0	
Df	29	
t Stat	0.573467	
P(T<=t) two-tail	0.570749	
t Critical two-tail	2.045231	

t-Test: Paired Two Sample for Means
Shores & Flats

	1995	2002
Mean	732.8	721.0
Variance	445651.5	452424.3
Observations	30	30
Pearson Correlation	0.947835	
Hypothesized Mean Difference	0	
df	29	
t Stat	0.297525	
P(T<=t) two-tail	0.768187	
t Critical two-tail	2.045231	

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E-2: ANOVA results and S-N-K separation of differences in change amounts between quads.

ANOVA RESULTS
Change between Quads and/or Change Type
Dependent Variable: Acres

Source	Sum of Squares	df	Mean Square	F	Sig.
corrected model	463444.4	42	11034.4	1.91	0.001
intercept	209987.2	1	209987.2	36.25	0.000
Quad	248595.3	29	8572.3	1.48	0.005
Change Type	214849.1	13	16526.9	2.85	0.001
Error	2183741.3	377	5792.4		
Total	2857172.9	420			
Corrected Total	2647185.6	419			

E-3: S-N- K mean separation results for differences in amount of change between change types

S-N-K
Change Type
Dependent Variable: Acres

		subsets	
Change type	N	1	2
Erosion/shrub	30	0.69	
development	30	1.607	
creation	30	3.423	
excavation	30	3.543	
Burial	30	3.967	
Erosion	30	4.56	
Erosion/upland	30	4.733	
man-made	30	19.843	19.843
accretion	30	32.377	32.377
Growth	30	32.543	32.543
subsidence	30	34.281	34.281
Erosion/marsh	30	39.57	39.57
Fill	30	57.767	57.767
Erosion/shore	30		74.133
Sig.		0.162	0.086

E-4: Tables of raw data for polygons selected for the 1993 vs. 1995 map comparison from Caplen, Christmas Point, Sea Isle, The Jetties, Umbrella Point, League City and Cove quads

	Habitat			
Quad		1993	1995	Changed/observed
Umbrella	E1UBL	E1AB		
Umbrella	U	E1UBLx		
Umbrella	U	E1UBL		
Umbrella	E1UBL	E1UBL		
Umbrella	U/E1UBL	E2USM		
Umbrella	E1UBL	E2USM		
Umbrella	E1UBL	E2USM		
Umbrella	U/E1UBL	E2USN		
Umbrella	E1UBL/U	E2USN		
Umbrella	E2USN	E2USN		
Umbrella	E2USN	E2USN		
Umbrella	U/E1UBL	E1AB		
Umbrella	E1UBL	E2USM		
				12/13
Cove	PEM1Fh	E2EM1P		
Cove	E2EM1P	E1UBL		
Cove	U	E2SS1P		
Cove	E1UBL	E2USM		
Cove	PEM1Fh	E1UBL		
Cove	E2EM1N	E2USM		
Cove	E2EM1P	E2EM1P		
Cove	E2EM1P	E2EM1P		
Cove	E2EM1P	E2EM1P		
Cove	E2EM1P	E2EM1P		
Cove	PEM1Fh	E2EM1P		
Cove	E2EM1P	E2EM1P		
Cove	L1UBHh	E1UBL		
Cove	E1UBL	E1UBL		
Cove	PEM1Fh	E2EM1P		
Cove	E2EM1N	E2EM1P		
Cove	PEM1Fh	E1UBL		
Cove	PEM1Fh	E2EM1P		
Cove	PEM1Fh	E1UBL		
Cove	PUBHh	E1UBL		
Cove	E2EM1P	E2EM1P		
				14/21

E4: continued

Quad	Habitat 1993	1995	Changed/observed
Cove	E1UBL	E2USM	
Cove	E2EM1P	E2EM1P	
Cove	PEM1Fh	E1UBL	
Cove	E1UBL	E1UBL	
Cove	E1UBLx	E2EM1P	
Cove	E2EM1P	E1UBL	
Cove	PEM1Fh	E1UBL	
Cove	L1UBHh	E1UBL	
			6/8
League city	E1UBL/U	E2EM1P	
League city	U	E2EM1N	
League city	E2EM1P/E2SS1P	E2EM1P	
League city	E1UBL/E2EM1Px	E2EM1P	
League city	E1UBL	E2EM1P	
League city	E2EM1Px/E1UBL	E2EM1P	
League city	E2EM1P/U	E2EM1P	
League city	E1UBL	E2EM1P	
League city	U	E2SS1P	
League city	E1UBL	E2UBM	
League city	E1UBL	E2USM	
League city	E1UBL	E2USM	
League city	E1UBL	E2USM	
League city	E1UBL	E2USM	
League city	U	E2USM	
League city	E1UBL	E2USM	
League city	E1UBL	E2USN	
League city	U	E2USN	
League city	E2EM1P	E2USNs	
League city	E1UBL	E2USM	
League city	PFO1T	E2EM1P	
League city	E2EM1P	E2EM1N	
League city	U/E2EM1P/E1UBL	E1UBL	
League city	E1UBL	E2USM	
			24/24
Sea isle	E1UBL	E1ABL	
Sea isle	E1UBLx	E1UBL	
Sea isle	E2EM1Ps	E1UBL	
Sea isle	E2EM1N	E2EM1N	
Sea isle	E2EM1N	E2EM1N	
Sea isle	E1UBL	E2EM1N	
Sea isle	E2EM1N	E2EM1N	
			3/7

E4: continued

Quad	Habitat 1993	Habitat 1995	Changed/observed
Sea isle	E2USN	E2EM1N	
Sea isle	E2EM1N	E2EM1N	
Sea isle	E2EM1N	E2EM1N	
Sea isle	E2EM1P	E2EM1N	
Sea isle	E2EM1P/U	E2EM1Ns	
Sea isle	E1UBL/E2EM1Ns	E2EM1Ns	
Sea isle	E2EM1P	E2EM1P	
Sea isle	E2EM1P	E2EM1P	
Sea isle	E2USP	E2EM1P	
Sea isle	E1UBL	E2UBM	
Sea isle	E1UBL/E2EM1N	E2UBM	
Sea isle	E2USP	E2UBP	
Sea isle	E1UBL	E2UBPs	
Sea isle	E2EM1N	E2UBP	
Sea isle	E1UBLx	E2USN	
Sea isle	E1UBL	E2USN	
Sea isle	E2EM1Ps/E2USN	E2EM1Ps	
Sea isle	E2EM1P	E2EM1P	
Sea isle	E2EM1Ns	E2EM1N	
Sea isle	E2EM1N	E2EM1N	
Sea isle	E2EM1N	E2EM1N	
Sea isle	E1UBL	E2EM1N	
Sea isle	E2EM1N	E2EM1N	
Sea isle	E1UBL	E1UBL	
Sea isle	E1UBLx	E1UBL	
Sea isle	E1UBL	E1UBL	
Sea isle	E1UBL	E1UBL	
			13/27
Jetties	E2USN	E2USN	
Jetties	E2USP	E2USP	
Jetties	E2EM1P	E2EM1P	
Jetties	E2USN	E2USN	
Jetties	E2USN	E2UBN	
Jetties	E1UBL	E1UBL	
Jetties	E2USN	E1UBL	
Jetties	E2USN	E2USN	
Jetties	E2USN	E1UBL	
Jetties	E2EM1P	E1UBL	
Jetties	E2USN	E1UBL	
Jetties	E2EM1N	E1UBL	
Jetties	E1UBL	E2EM1N	
			6/13

E4: continued

Quad	Habitat	1993	1995	Changed/observed
Jetties	E1UBL	E1UBL		
Jetties	M2USN	M2USN		
Jetties	E2EM1N	E1UBL		
Jetties	E2EM1P	E2EM1N		
Jetties	E1UBL	E2EM1N		
Jetties	E1UBL	E1UBL		
Jetties	E2USP/E2EM1P	E2USP		
Jetties	E2EM1P	E1UBL		
Jetties	E2EM1N	E2EM1N		
Jetties	E1UBL	E1UBL		
Jetties	E2USN	E2USP		
Jetties	E2EM1P/E2EM1N/U	E2EM1P		
Jetties	E2EM1P	E2EM1P		
Jetties	M2USN	M2USN		
Jetties	E2USN/E2EM1P	E2UBP		
Jetties	E2USN	E2USN		
Jetties	E2USN	E1UBL		
Jetties	E1UBL	E1UBL		
Jetties	E1UBL	E2EM1N		
Jetties	E1UBL	E2EM1N		
				11/20
Caplen	E1UBL	E2USN		
Caplen	E1UBL	E2EM1N		
Caplen	E2EM1P	E2EM1N		
Caplen	E2EM1P	E1UBM		
Caplen	E1UBL	E2EM1N		
Caplen	E2EM1N	E2EM1N		
Caplen	E1UBL	E1AB		
Caplen	E2EM1N	E1UBM		
Caplen	E2EMIN/E1UBLx	E2EM1N		
Caplen	E2USN	E2UBP		
Caplen	E2EM1N	E1UBM		
Caplen	E2EM1P/PEM1A	E2EM1P		
Caplen	E1UBLx	E2EM1N		
Caplen	E2EM1N	E1UBM		
Caplen	E2EM1N	E2EM1N		
Caplen	E1UBLx	E2USP		
Caplen	E2EM1N	E2EM1N		
Caplen	U	E2EM1P		
Caplen	E2USN	E1UBL		
				15/20

E4: continued

	Habitat		
Quad	1993	1995	Changed/observed
Caplen	E2USNs	E2USN	
Caplen	E1UBLx	E1UBL	
Caplen	E2EM1P	E1UBL	
Caplen	E2EM1N	E2EM1N	
Caplen	E2USP	E2USP	
Caplen	E1UBL/E2EM1N	E2EM1P	
Caplen	E2EM1N	E2USP	
Caplen	E2EM1N	E2EM1N	
Caplen	E1UBLx	E1UBLx	
Caplen	E2EM1N	E2UBM	
Caplen	PEM1Ahs	E2EM1Ps	
Caplen	U	E2EM1Ps	
Caplen	E1UBLx	E1UBL	
Caplen	E1UBLx	E2USN	
Caplen	E2EM1N	E2UBM	
Caplen	U	E2EM1P	
Caplen	E1UBLx	E2USN	
Caplen	E2EM1N	E2EM1N	
Caplen	E1UBL	E2UBM	
Caplen	E2EM1N	E2UBM	
Caplen	E2EM1N	E2UBM	
Caplen	U	E2EM1N	
Caplen	U	E2EM1N	
Caplen	E2EM1P	E2EM1P	
Caplen	E1UBLx	E1UBL	
			15/25
Christmas point	E1UBL	E2UBM	
Christmas point	E1UBL	E2UBN	
Christmas point	PEM1C/U	E2EM1N	
Christmas point	E2EM1N	E2EM1N	
Christmas point	E2EM1N	E2EM1N	
Christmas point	E1UBL	E2UBM	
Christmas point	E1UBL	E2UBN	
Christmas point	E1UBLx	E1UBLx	
Christmas point	E1UBL	E2USN	
Christmas point	E1AB3L	E2USM	
Christmas point	E1UBL	E2UBN	
Christmas point	E1UBL	E2USN	
Christmas point	E2EM1N	E2EM1N	
Christmas point	E1UBL	E2UBP	
			10/14

E4: continued

	Habitat		
Quad	1993	1995	Changed/observed
Christmas point	E1UBL	E2UBM	
Christmas point	E1UBL	E1UBL	
Christmas point	E1UBL	E2EM1N	
Christmas point	E2USN	E2USN	
Christmas point	E1UBL	E2EM1N	
Christmas point	E1UBL	E2EM1N	
Christmas point	E1UBL	E1UBL	
Christmas point	E2USN	E2UBM	
Christmas point	E2EM1N	E2EM1N	
Christmas point	E1UBL	E2UBN	
Christmas point	E1UBL	E2EM1N	
Christmas point	E1UBL	E2EM1N	
Christmas point	E1UBL	E2UBM	
Christmas point	E2EM1N	E2EM1N	
Christmas point	E1UBL	E2USM	
Christmas point	E1UBL	E2USM	
Christmas point	U	E2SS1P	
Christmas point	E2EM1P/U	E2UBP	
Christmas point	E1UBL	E1UBL	
Christmas point	E1UBL	E1UBL	
Christmas point	E2EM1Ps/U	E2EM1N	
			13/21
Total			142/213

E-5: Results of paired t-test comparing randomly selected polygons from 1993 and 1995 to determine if there is asignificant change in acreage due to boundary changes.

t-Test: Paired Two Sample for Means

	1993	*1995*
Mean	1938.9	253.7
Variance	54716849	2511572
Observations	120	120
Pearson Correlation	0.42896	
Hypothesized Mean Difference	0	
Df	119	
t Stat	2.687831	
P(T<=t) two-tail	0.008222	
t Critical two-tail	1.980097	

VITA

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Research Assistant, TAMUG , Galveston, Texas (February 2003- August 2005)

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Wetlands Consultant, SMC Consulting, Pearland, Texas

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